Simulation of the North Atlantic Air Traffic and Separation Scenarios

NICE-USA Report

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16. Abstract

This report presents a comprehensive study of the air traffic over the North Atlantic (NAT) Ocean. The main purpose of the study is to assess the fuel savings benefit of proposed changes to the separation standards in the NAT Minimum Navigation Performance Specification (MNPS) airspace. The report describes in detail the purpose of the study, literature survey of relevant work, requirements for the air traffic simulation, various separation standard scenarios, validation of the simulation model, analysis of the results, and conclusions. Using the separation standards from the 1996 NAT system as the baseline, this study presents analysis of four different separation scenarios: Reduced Vertical Separation Minima, Reduced Vertical and Longitudinal Separation Minima, Reduced Vertical and Horizontal Separation Minima, and Free Flight. A fast time simulation model is used to investigate the effect of the separation scenarios on several measures of system performance such as fuel consumption and communication loadings. This study was completed in cooperation with the NAT Implementation Management Group Cost Effectiveness (NICE) Task Force. The results presented in this report represent the findings of the NICE-USA Task Group.

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Table of Contents

Table of Contents (Cont)

Page

Appendixes

List of Illustrations

List of Illustrations (Cont)

List of Illustrations (Cont)

Tables | Page

Executive Summary

This report presents a comprehensive study of the air traffic over the North Atlantic (NAT) Ocean. The main purpose of the study is to assess the fuel savings benefit of proposed changes to the separation standards in the NAT Minimum Navigation Performance Specification (MNPS) airspace. This report describes in detail the purpose of the study, literature survey of relevant work, requirements for the air traffic simulation, various separation standard scenarios, validation of the simulation model, analysis of the results, and conclusions.

As identified in the Federal Aviation Administration (FAA) Strategic Plan for Oceanic Airspace Enhancements and Separation Reductions, one of the key components of the enhanced oceanic Air Traffic Management (ATM) system that supports the pilots, airlines, Air Traffic Control Specialists (ATCSs), and traffic management specialists is improvement in separation standards [4]. One of the major benefits of the enhanced oceanic ATM system identified in the Strategic Plan is fuel savings. With the continued increase in air traffic volume, fuel optimal routes within the airspace are becoming less available due to congestion. Reduced separation standards increase the capacity of the airspace allowing more aircraft to operate at or close to an optimal flight plan. Aircraft that operate on a flight plan at or close to optimal will use less fuel than aircraft that are rerouted onto a flight plan not located near the optimal.

This study investigates several scenarios, each with different reduced separation standards. Simulation experiments are used to study the fuel savings benefits from each scenario. Specifically, the following separation standard scenarios are investigated

a. Baseline System (2000 ft Vertical, 60 nm Lateral, 10 minute Longitudinal, 15 minute Crossing)

b. Reduced Vertical Separation Minima (RVSM) (1000 ft Vertical, 60 nm Lateral, 10 minute Longitudinal, 15 minute Crossing)

c. Reduced Vertical and Longitudinal Separation Minima (RVLSM) (1000 ft Vertical, 60 nm Lateral, 7 minute Longitudinal, 10 minute Crossing)

d. Reduced Vertical and Horizontal Separation Minima (RVHSM) (1000 ft Vertical, 30 nm Lateral, 5 minute Longitudinal, 10 minute Crossing)

e. Free Flight with no separation requirements, this is the "theoretical best case " scenario, it is not realistic and cannot be implemented in the real world

This work was completed as part of the NAT Implementation Management Group (IMG) Cost Effectiveness (NICE) Task Force. The FAA and Rutgers University (NICE-USA Task Group) collaborated in the completion of this study.

The NICE-USA Task Group developed two models, the Flight Planning Model (FPM) and Flight Tracking Model (FTM). The FPM is an optimization model that utilizes a forward dynamic programming search algorithm to determine the optimum flight plan for each flight. Once the optimum flight plans are obtained, the FTM performs clearance procedures. In the FTM, Air Traffic Control rules specific to each separation scenario are applied and aircraft request step climbs. The FTM model produces the cleared flight plans, fuel burn calculations, and other measures of the system performance such as the volume of communication traffic in the NAT

airspace. The primary performance measure of the system is the aircraft fuel consumption. Some key results of the NICE-USA simulation studies are as follows:

- A mean fuel burn saving for RVSM of 0.55% of total fuel in 1996, rising to 0.68% in 2010. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to a savings of over $15 Million in 1996 to a savings of over $25 Million in year 2010.
- A further mean fuel burn saving of 0.06% for RVLSM over RVSM. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to an additional savings for RVLSM over RVSM of more than $1.8 Million in 1996 to a savings of over $2.1 Million in year 2010.
- A mean fuel savings of 0.18% for RVHSM over RVSM when communication efficiency is assumed to stay at the current level. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to an additional savings for RVHSM over RVSM of more than $5.6 Million in 1996 to a savings of over $5.9 Million in year 2010.
- For the 'pot-of-gold' Free Flight scenario, a mean fuel burn saving of 2.08% over RVSM. At the US fuel price of $0.51/gallon (Averaged from May 1998 to April 1999) this equates to an additional savings for Free Flight over RVHSM of more than $54 Million in 1996 to a savings of over $70 Million in year 2010.
- The ATC communication loadings increase with increasing traffic. However, a decrease in ATC conflict detection and resolution activities was realized in all separation scenarios when compared to the Baseline System.

The results presented in this report represent the findings of the NICE-USA Task Group. The complete NICE Task Force results are presented in [9].

1. Introduction

This study investigates the effects on potential benefits from improvements to the oceanic Air Traffic Control (ATC) system in the North Atlantic (NAT) Minimum Navigation Performance Specification (MNPS) airspace. Specifically, this study provides an investigation into fuel savings resulting from improvements in the separation standards in the NAT MNPS.

One of the key components of the enhanced Oceanic Air Traffic Management (ATM) system that supports the pilots, airlines, Air Traffic Control Specialists (ATCSs), and traffic management specialists is improvements in separation standards [4]. One of the major benefits of the enhanced Oceanic ATM system is fuel savings.

The strategy for implementing proposed separation reduction initiatives in the NAT follows a phased progression. The first separation reduction implemented is Reduced Vertical Separation Minimum (RVSM). The remaining separation reductions to be implemented include Reduced Horizontal Separation Minima (RHSM) Phase I and II Reduced Vertical and Longitudinal Separation Minima (RVLSM), RHSM Phase III Reduced Vertical and Horizontal Separation Minima (RVHSM) and oceanic Free Flight.

The NAT Implementation Management Group (IMG) formed a task force in March 1995 to study the benefits associated with the separation reduction elements of the Air Traffic Management Implementation Plan (ATMIP). Three task groups participate in the NAT IMG Cost Effectiveness (NICE) Task Force; NICE-UK from the United Kingdom (UK National Air Traffic Services, (NATS) LTD), NICE-ICE from Iceland (Icelandic Civil Aviation Authority (CAA) and the University of Iceland) and NICE-USA from the United States (FAA and Rutgers University). The three groups routinely discuss methodologies and modeling procedures. Each group develops and maintains its own air traffic simulation models.

1.1 Background

The NAT airspace is defined as the airspace through which all aircraft traveling between North America and Europe operate. Most aircraft prefer to operate at high altitudes and within a specific geographical range in order to minimize the fuel consumption and flight time. To accommodate this need, the NAT MNPS portion of airspace contains the most desired altitudes and latitudes. The NAT MNPS airspace is the portion of NAT airspace between Flight Level (FL) 290 and FL 410 from latitude 27 degrees north to the North Pole, bounded in the east by the eastern boundaries of control areas Santa Maria Oceanic, Shanwick Oceanic and Reykjavik, and in the west by the western boundary of CTA (Control Area) Reykjavik, the western boundary of CTA Gander Oceanic and the western boundary of CTA New York Oceanic excluding the area west of 60 degrees West and south of 38 degrees 30 minutes North. Figure 1 shows the NAT MNPS and the five Oceanic CTA.

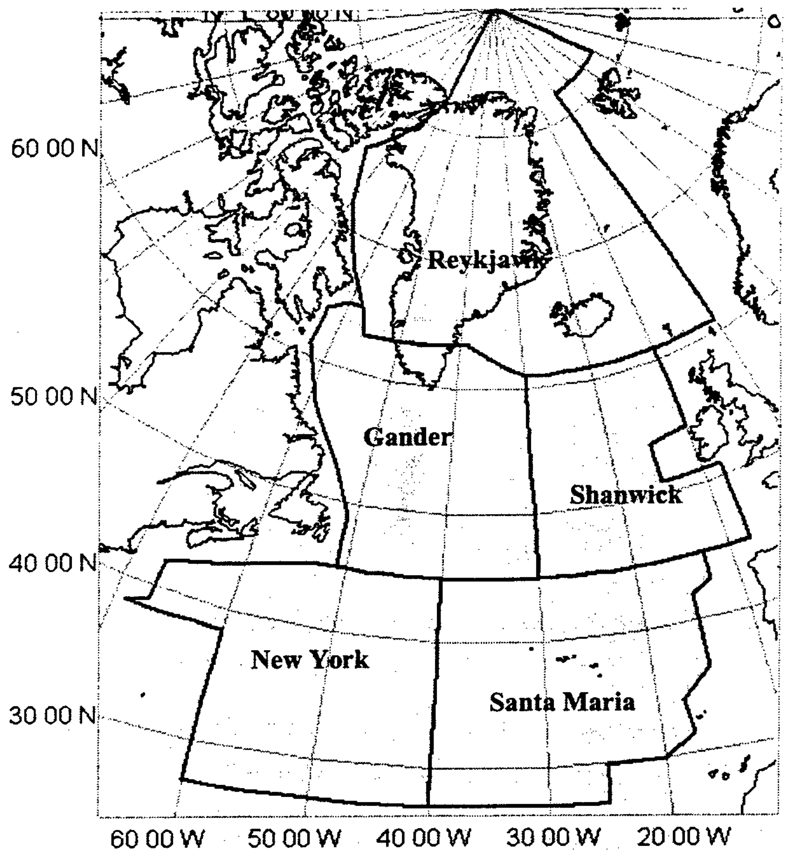


Figure 1. NAT MNPS area.

Most of the traffic passes through two of these Oceanic Area Control Centers (OACCs), the Gander CTA, which falls under the authority of Transport Canada and the Shanwick CTA, which is operated by the UK NATS Limited. The New York CTA is operated under the authority of the FAA and the Department of Transportation (DOT) in the United States. The Reykjavik CTA falls under the authority of the Icelandic CAA. The Santa Maria CTA is operated under the authority of the Director General of Civil Aviation and Airports and the Air Navigation Public Enterprise, Portugal.

The two major directions of air travel in the NAT MNPS are east and west. Aircraft traveling between North America and Europe comprise the large majority of traffic each day. The NAT traffic follows a systematic schedule. The traffic begins each day with eastbound flights lasting roughly 10 hours. A change-over period occurs before the main surge of westbound traffic begins. This keeps the peak periods of traffic in a unidirectional flow and simplifies the tasks of the ATCSs. These unidirectional traffic flows occur because of the lack of sophisticated surveillance equipment such as radar coverage over the NAT Ocean. The ATCSs must coordinate the crossing of each aircraft with the other OACCs to ensure safe flight operations.

There are significant weather patterns in the NAT airspace that cause certain areas to be optimal for flight operations. The most significant weather pattern in the NAT is the Jet Stream. It is a narrow core of strong easterly winds, which is almost always present. Due to the direction of these winds, the eastbound aircraft usually plan to travel within the Jet Stream. Knowledge of the location of the significant winds help the eastbound flights shorten their travel times and save

fuel by utilizing the tail winds. The westbound flights also benefit from the knowledge of the location of these winds as it helps them to avoid the strong head winds that would increase their travel time and burn more fuel. As a result of the Jet Stream, certain areas of the NAT are optimal for flight operations. The location of the optimal airspace changes daily and depends on the direction of flight.

To accommodate the aircraft that plan to travel in the optimal airspace, planners from the OACCs develop an Organized Track System (OTS) each day. The OTS is established when current meteorological information and forecasts are available to the OTS planners. The OTS can be thought of as 'highways in the sky.' It consists of specific latitude - longitude combinations that constitute the optimal airspace. A new OTS is defined each day, and a separate OTS is defined for each direction. The OTS for each direction consists of several tracks (the individual routes defined in the system). Each track is assigned specific flight levels. Aircraft that operate on one of the defined OTS tracks are referred to as OTS aircraft. Aircraft that do not operate on a defined OTS track are referred to as Random aircraft.

The current oceanic ATC system is procedurally based, relying heavily on filed flight plan data. Tracking the progress of aircraft through the NAT oceanic airspace is accomplished with infrequent position reports sent by the aircraft. The infrequency of position reports combined with limitations in navigational accuracy and communications have resulted in the large separation standards that are currently in place. Large separation minima limit the ability of the controller to grant preferred routes based on wind data or altitude profiles and contributes to flow restrictions at peak hours [4], which result in increased fuel consumptions and travel time.

1.2 Separation Scenarios

This study investigates the effect of the separation standards within the NAT MNPS airspace on the system performance. Using the separation standards from the 1996 NAT system as the baseline, this study presents analysis of four different separation scenarios as shown in Table 1.

Table 1. Separation Scenarios

ATMIP Scenario	**NICE-USA notation**	**Separation Standards**			
		Vertical	**Lateral**	**Crossing**	**Longitudinal**
Pre-RVSM Baseline	Baseline	2000 feet	60 nm	15 minutes	10 minutes
RVSM	RVSM	1000 feet	60 nm	15 minutes	10 minutes
RHSM (Phase 1 and 2)	RVLSM	1000 feet	60 nm	10 minutes	7 minutes
RHSM (Phase 3)	RVHSM	1000 feet	30 nm	10 minutes	5 minutes
Free Flight[1]	FF	0	0	0	0

[1] Free Flight scenario is the "theoretical best case" scenario. The latest meteorological data are available during flight planning. All flights carry out their optimal fuel flight plans without regards top other aircraft in the system. No separation standards are imposed. This scenario is not realistic and cannot be implemented in the real world.

To compare the benefits associated with each of the separation scenarios, the NICE-USA Task Group developed a fast time simulation model. We compare the results from the simulation of separation scenarios to the other scenarios to estimate the benefits of the system. Figure 2 shows an overview of the activities that occurred during the development of the model. All of the activities are completed in cooperation with the NICE Task Force. For example, we validate the NICE-USA model against real data, the NICE-UK model (NATSIM), and the NICE-ICE model (AMELIA).

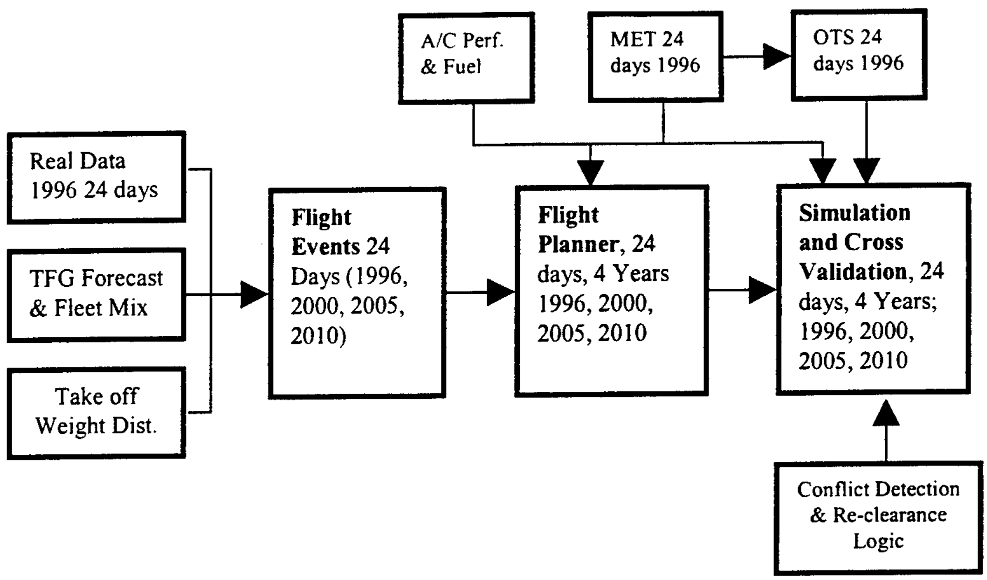


Figure 2. Model development activity.

In this study, we investigate the effect of the separation standard scenarios on several measures of performance such as fuel consumption and communication loadings. We begin with a literature review of previous oceanic studies; we then present the requirements needed in the model development, we then discuss the simulation model and assumptions, the cross validation and verification results, the simulation results, and we conclude the simulation study.

2. Literature Review

A thorough review of the literature showed that there are four oceanic models that dealt with modeling air traffic over oceanic systems. All of these models use computer simulation to investigate the oceanic system of interest. Three of these models have been designed and implemented for the NAT Ocean air traffic, and the fourth is a model of a similar system in the Pacific Ocean. The analysis focuses on the scope, basic framework, main results, and possible shortcomings of each model.

2.1 Flight Cost Model

2.1.1 Scope

One of the early NAT simulation models implemented in 1981 of the actual 1979 system is the Flight Cost Model (FCM) designed by SRI International under contract by the FAA of the United States. The main objective of this model is to determine the potential cost savings of proposed changes to NAT airspace separation standards, as the result of the potential implementation of various system improvements (e.g., satellite data link and airborne separation devices) [2].

The FCM is the most comprehensive of the simulation models reviewed. The scope of the FCM is the incorporation of several substantial system elements. Weather information is included as wind vectors and temperatures at four barometric altitudes. Actual domestic and oceanic routings are amassed to define a finite network of flight segments. Aircraft characteristics (e.g., type, fuel burn profile, and weight) are compiled to determine fuel consumption and optimal flight plan or path. Clearance resolution procedures, classified by domestic and oceanic (OTS or non-OTS) flight regions, are utilized to provide conflict analysis algorithms. Finally, the FCM combines these elements to simulate the aircraft flight from take-off to landing airport [3].

2.1.2 Basic Framework

The FCM is a detailed model of the 1979 NAT air system written in a discrete time simulation language called SIMSCRIPT II.5. The program is divided into six basic components, including

a. Network Generating Routine (NGR)

b. Track Setting Routine (TSR)

c. Meteorological Routine (MET)

d. Flight Planning Model (FPM)

e. Flight Tracking Model (FTM)

f. Report Generating Package (RGP)

The two main components are the FPM and FTM with the other four being supporting modules [13].

The NGR uses a composite listing of current domestic routes and feasible oceanic route structures to define a network of waypoints (nodes). This program's main function is to provide some *finite limit* to the amount of feasible flight paths created. This process serves to enhance the performance of the entire model by reducing memory requirements and accelerating computation time.

The TSR defines a network of links and flight levels from a data input file. The routine matches these links with existing links already defined by the NGR. It assigns flight levels to the tagged links.

The MET reads weather information from the United States Weather Bureau National Meteorological Center at Suitland, MD into the model. The forecast winds (magnitude and direction) and temperatures are given at four levels: 400mb, 300mb, 250mb, and 200mb. From these data, the routine extracts the winds and temperatures for the northern hemisphere. If a link of the network is outside MET data range, zero wind and standard temperature are defined for this link's nodes.

The FPM determines the optimal flight plan request. This process is driven by an input day flight schedule consisting of departure time, arrival time, aircraft type, origin airport, destination airport, and other flight schedule factors. The FPM uses a 'backward dynamic programming technique' to determine this optimal flight plan. It performs an iterative search starting with the origin airport or node. Using a pre-defined search angle and the nominal direction of the flight, the algorithm determines the route with minimum fuel cost. This route is defined as the flight plan and is sent to the next module as a requested flight path.

The FTM acts as the ATCS. It assigns flight plans, tracks all traffic, and resolves potential conflicts. Using the departure time from the current flight schedule, it determines the arrival time of the first node. If a conflict is detected, it delays the aircraft on the ground until the conflict is clear.

When the aircraft arrives at its first node after ascent and cruise speed is reached, clearance is initiated. The clearance process checks if the aircraft has been cleared beyond the current node. If it is not, new clearance is required. For domestic airspace, the clearance only includes the next node, but, for oceanic airspace, it is usually more than one (the remainder of the crossing). The domestic flight level requested is taken from the flight plan. The oceanic flight level requested is given in the flight plan and assumed constant for the entire crossing.

During the clearance process, an aircraft flight plan is tested for conflicts. When no conflicts exist, the airspace is reserved. If the clearance detects conflicts, procedures are performed to determine a conflict free path. This may result in a different flight plan cleared than originally requested. If the conflict resolution procedures should fail, the aircraft flies its original flight plan without reserving the airspace and the clearance procedure is revoked again on the next arrival node. Finally, after clearance status is complete, the module determines the time of arrival (TOA) to the next node and further processing is suspended until that time.

Oceanic aircraft arriving at nodes that require no reclearance are checked for a possible step-climb. If the flight plan indicated a higher FL is economical, a step-climb request is invoked. The module then initiates reclearance at the higher FL. If other aircraft are in conflict with the new flight plan request, the aircraft stays at the original altitude.

The RGP compiles the results of the previous modules and creates an information log of all simulation events and 11 simulation reports. These reports include hourly instantaneous aircraft counts for each flight region, the fuel burn of daily traffic, and several other performance calculations.

2.1.3 Main Results

As published in the Oceanic Area System Improvement Study (OASIS) in 1979, the FCM produces results on flight cost related to fuel consumption from congestion and weather influences. The model determines three main cost modes. The first was defined as *the ideal flight cost*. It was based on aircraft operating without restrictions in oceanic airspace, except with 1000 feet separation minima and constrained to domestic routings. The FCM does not allow a cruise-climb profile (where aircraft follow an optimal continuous parabolic like path). However, it assumes a step-climb profile subject only to vertical separation requirements.

The second cost mode is the *planned flight cost*. It is the flight cost associated with the flight plan requested by the aircraft. It is based on domestic and oceanic route and altitude restrictions with no Air Traffic System (ATS) intervention. The third cost mode is the *actual flight cost*. It is based on the actual cleared flight profile that is the result of the clearance checks of conflicts with other aircraft. The actual flight profile is the flight path of the aircraft affected by congestion.

All three classifications of cost are influenced by weather factors. The three values are utilized to examine various configurations of proposed separation minima, which determines the most economical alternative. The analysis uses summer and winter sample days in 1979 to illustrate the seasonal impact on the cost alternatives. The analysis also forecasts traffic to year 2005.

2.1.4 Limitations

The major shortcoming of the FCM is that it models the NAT air system as described in mid 1979. The system is quite different today. Domestic routings have been changed considerably with the implementation of the Expanded East Coast Plan in the late 1980s and the many restructurings of the terminal airspace routes. The longitudinal time separation is 10 minutes and a lateral separation of 60 nm as opposed to 120 nm then. The operational procedures have changed as well, which can be easily illustrated by examining the differences between the FCM conflict resolution strategies and the current methods.

Another significant shortcoming is that the FCM does not consider communication loadings or capacities in the model design or analysis of results. Communication is an important system parameter, especially with the strategic nature of control over the NAT oceanic airspace.

2.2 The North Atlantic Track Model

2.2.1 Scope

The North Atlantic Track (NATRACK) model developed in 1988 by the CAA of the UK simulates the NAT air traffic from take-off to landing. The model assesses the congestion penalty (cost associated to traffic volume conflicts causing unavailability and inefficiency of optimal flight paths) and level cruise penalty (cost associated to convention of flying on fixed flight levels as opposed to cruise-climbing). The model generates flight requests from empirical distributions, determines flight clearances, and tracks aircraft across NAT airspace, grants step-climbs when appropriate for westbound OTS and non-OTS only [1].

2.2.2 Basic Framework

The NATRACK model is composed of three main modules. The first, NATCONV, uses the flight data process system from the Shanwick database of NAT oceanic movements. With the database information, it constructs empirical distributions of clearance requests. The model uses this in the next module, which is composed of the following eight sub-modules:

a. NAT - coordinate the execution of the other sub-modules
b. READ - read the input file determined by NATCONV
c. INTERAC – determines the crossings and calculated the distances on tracks to interactions
d. ASSIG - randomly generates flight requests using statistics read by the READ module
e. CLEAR – determines conflicts and reclears aircraft to a different track, flight level, speed, and so on.
f. CLIMBREQ - simulates the requests for clearances of step-climbs in the NAT
g. PENCALC - calculates fuel penalty
h. OCC - calculates occupancy values

The final main module, OUTPUT, produces the results of the iterations such as fuel costs and occupancy values.

2.2.3 Main Results

The results of the NATRACK model are composed of both economic and safety measures. The economic measures include fuel penalties in percentage of monetary terms due to reclearances and refusals of step-climbs, counts of aircraft cleared as requested at oceanic entry or given reclearances of various types, and several others. The safety measures include lateral and longitudinal occupancy values calculated from proximate pair counting during the simulation run. Both economic and safety measures are used for comparative analysis of various separation minima configurations [12].

2.2.4 Limitations

One important shortcoming of the NATRACK model is that it only considers westbound OTS and non-OTS traffic. Eastbound traffic is not considered due to "limitations on the number of aircraft that the NATRACK model can simulate" [1].

Meteorological influences are also not considered because the original assumption is that both eastbound and westbound weather influences would average out. However, as stated previously, the NATRACK model simulates westbound traffic only.

Another limitation of the NATRACK is that it uses only four sets of aircraft statistics. It is suggested that more aircraft characteristics be used to increase accuracy of the model [12]. The NATRACK model also does not consider communication loadings as capacity constraints or output.

2.3 The North Atlantic Traffic Allocation Model

2.3.1 Scope

Transport Canada developed the North Atlantic Traffic Allocation Model (NATTAM) in 1991. The main objective of the model is to estimate occupancy for NAT airspace to determine the safety impact of changes made to separation standards. The model reads flight plans as input and then simulates these aircraft from take-off to landing. The NATTAM checks and resolves conflicts by using documented reclearance strategies. The NATTAM also enables the user to concentrate traffic to core tracks and then examines the output occupancy information [5].

2.3.2 Basic Framework

The NATTAM is written in the PASCAL computer language. The model is designed with an integrated menu environment and friendly prompts for input. The program starts with a choice of two menus, Stats or Main Menu.

Stats lists the current file defaults such as the file name of the flight schedule. The Main Menu is composed of the Flight Editor, Track Structure Editor, Run Simulator, Change Variables, Print Flight Schedule, Print Track Structure, and Quit prompts. The Flight Editor prompts the user for the flight plan input file. The Flight Editor allows the user to alter the flight schedule in several ways. The user can edit the flight schedule, make the track identifiers in the flight plan file match the current tracks, change the flight plan coordinates to match current tracks, create conflicts in peak and uniform modes, and perform other tasks such as concentrating flights laterally. Another choice, Change Variables, in Main Menu allows the user to set separation standards and choose legal flight levels. The Track Structure Editor enables the user to generate tracks from input files, the current flight schedule, or entered coordinates [10].

The Simulator Mode executes the simulation using the input files and choices previously made in the editors. It uses the flight plan input file as the requested flight plans and simulated the ATS functions, tracking the cleared aircraft. If the current aircraft is determined to be in conflict, the aircraft is cleared for other conflict free routes. The decision process of resolving the conflicts is documented in the form of a decision tree. The program uses the decision tree to try different alternatives to achieve a conflict free path through the NAT airspace. The output functions print the rerouting results, decision tree paths, current track structures, and others such as the simulator running constants.

2.3.3 Main Results

The NATTAM provides safety measures as occupancy values to various system parameters. The major focus of the model is to examine the safety impact to variable separation standards and core track concentrations of traffic, which utilizes user-friendly menu prompts. Also clearance counts, such as number of requested accepted or not accepted step-climbs, are output by NATTAM [6].

2.3.4 Limitations

The major shortcoming of NATTAM is that it does not generate flight plans. The NATTAM cannot produce flight requests stochastically. It can only accept them as input, then it tracks the flight and alters the flight plan due to congestion situations.

The NATTAM does not provide cost results and does not consider communication loadings. Also, the NATTAM assumes the flight path requested already has taken meteorological forecasts into account. As a result, NATTAM does not provide any weather influences.

2.4 The North Pacific Track System Model

2.4.1 Scope

The FAA developed the North Pacific (NOPAC) Track System computer simulation model in 1984. The main objective of the model is to examine the safety impact of composite separation already implemented in 1982. The model uses empirical flight data to create statistical distributions that are used to generate flight plan requests. Using the system flight clearance methodology and the *fixed track* coordinates of the NOPAC Track System, the model determines occupancy values and cost implications of the recent structure change. The model also extrapolates navigational performance information from the NAT to examine the safety results.

2.4.2 Basic Framework

The NOPAC computer simulation model is written in the FORTRAN computer language. It represents a discrete time model of the oceanic air traffic to provide comparative analysis of the total system fuel burn, step-climb advantage, and route occupancy due to congestion influences [8].

The first phase of the model consists of the flight planning operations. An algorithm based on empirical data generated the flight requests. Next, the model determines the path assignments using probability distributions. Each choice is evaluated for conflicts before being allocated. If all paths are considered and no choice made, the aircraft waits 5 minutes and began again with the first choice. When a path is finally selected, information including the take-off time, aircraft type, path, direction, and take-off weights are stored. Step-climbs are also generated and considered if the climb is both cost effective and conflict-free.

At the start of a flight or step-climb event, a position update is executed to track the departure times, step-climbs, and weight changes of the aircraft on their routes. Fuel adjustments are calculated with altitude changes from step-climbs, recorded by aircraft type and terminal. The position updates are also used to calculate collision risk information.

2.4.3 Main Results

The FAA determines the economic benefits for comparative analysis of the pre-1982 system, where the track system consisted of three routes separated by 100 nm lateral separations and by 2000 feet vertical separations. The composite structure implemented in 1982 consists of five routes with simultaneous separations of 50 nm and 1000 feet vertically. The economic benefits

focuses on the fuel consumption savings associated with availability of the more fuel-efficient flight paths upon entry into the system [8].

Although the economic benefits are analyzed, the main focus of the model is to examine the safety implications of the new system. The same direction and opposite direction traffic proximate pair counts for both composite and non-composite systems are generated using the model output. Navigational performance information is extrapolated from NAT MNPS airspace based on the similarity of equipment and operational procedures. Finally, the Reich Model is employed to examine the lateral collision risk and compared for both systems.

2.4.4 Limitations

One of the main limitations for this study of the NOPAC Track System model is that it was developed for another system. There are many differences in the actual network of routings, both domestic and oceanic, in the NOPAC system compared to the NAT. However, the main consideration is that the NOPAC model has *fixed tracks,* not a changing track system such as the NAT OTS. Therefore, no track construction routines are required for the NOPAC, only an input function for the fixed track coordinates. This allowed the model to determine flight plan requests as simply a demand function. The NOPAC model does not consider meteorological influences and communication loadings.

2.5 Summary of the Oceanic Computer Simulation Models

a. The FCM, the most inclusive model, simulates the entire flight incorporating weather influences, routing restrictions, separation standards, and conflict strategies. The FCM is utilized to compare fuel consumption costs from various separation configurations and traffic congestion levels. Developed in 1979, one of the major limitations of the FCM is that it models an oceanic system approximately 20 years old.

b. The NATRACK model simulates aircraft crossings of westbound traffic over the NAT. Using empirical distributions for flight requests and flight clearance algorithms based on Shanwick ATS operations, the NATRACK model evaluates both economic and safety parameters. However, weather influences and communication loadings are not considered. Also, the model only simulates one direction of traffic, westbound, and utilizes a rather small set of aircraft characteristics.

c. The NATTAM simulates aircraft crossings of the NAT airspace. The NATTAM requires the input of the flight plans and track structure. Utilizing conflict resolution decision trees, the NATTAM tracks the aircraft flight across the NAT. The model offers users easy menus to alter system parameters and run the simulator. The model mainly determines the safety impact of alternative flight plans and parameter choices. It does provide very comprehensive alternatives, including changes to traffic concentrations to core tracks. However, the NATTAM does not provide cost output or consider weather influences and communication loadings.

d. The NOPAC model simulates the entire flight of aircraft flying in the North Pacific air system. This system, different from the NAT in several ways, has a fixed track system. With a fixed track structure, the NOPAC model uses demand functions to enter tracks and monitors the flights during their crossings. The main result of the NOPAC model is

the occupancy values in comparing systems in the pre- and post-composite separation modes.

3. Requirements

The simulation models developed in this report require extensive input, analysis of historical data, future changes in air traffic forecast, aircraft types, and OTS. The following subsections describe those requirements in detail.

3.1 Traffic Data

The Gander OACC provided preliminary traffic samples for the study. NICE-ICE provided the real 1996 traffic data for the 4th and 15th of every month. These data are collected by Iceland radio. The real traffic data include the aircraft type, origin and destination airports, take-off time, ground speeds, and waypoint crossing data.

Missing from the real traffic samples are the payload and take-off weight information. Samples of these data are collected from airlines so that accurate payload and take-off weight distributions could be generated.

3.2 Traffic Forecasts

The Traffic Forecasting Group (TFG) provides traffic forecasts for the NAT airspace. These include forecasts for the number of flights in the years 2000, 2005, and 2010. Other forecasts include the percentage increase in total traffic by season (winter and summer), percentage of directional traffic per entry hour by season, and percentage of traffic by regional pairing. The 1996 TFG distribution of aircraft types for the NAT airspace is shown in Table 2.

Table 2. TFG Aircraft Types

	Aircraft	Percentage	Cumulative Percentage
1	B767	28.7	28.7
2	B747	24.8	53.5
3	DC10	8.6	62.1
4	L1011	7.9	69.9
5	EA31	5.1	75.0
6	B74F	4.6	79.6
7	MD11	3.7	83.4
8	B757	3.2	86.6
9	EA34	2.9	89.5
10	Miscellaneous Jets	2.5	92.0
11	B777	--	--

The NICE forecast table for fleet types suggested at the March 1997 NICE meeting was accepted by the TFG. This forecast for the future years of 2000, 2005, and 2010 provides a distribution for each aircraft type. Some of the aircraft types did not appear in the forecast for the future years as the older aircraft are expected to be replaced by newer types in the NAT.

The NICE forecast table for fleet distributions is shown in Table 3. The percentage of increase/decrease to each aircraft type distribution is based on the 1996 distribution levels in Table 2.

Table 3. NICE Aircraft Type Distribution/Replacement Forecast

Aircraft	**Year 2000**	**Year 2005**	**Year 2010**
B767	No change	+100 % EA31 +100 % B757	+100 % EA31 +100 % B757
B747	No change	-30 % B777 -20 % B757	-60 % B777 -40 % EA34
DC10	-30 % B777 -20% EA34	-60 % B777 -40 % EA34	-60 % B777 -40% EA34
L1011	-30 % B777 -20 % EA34	-60 % B777 -40 % EA34	-60 % B777 -40 % EA34
EA31	No change	-100 % B767	-100 % B767
B74F	No change	No change	No change
MD11	No change	No change	No change
B757	No change	-100 % B767	-100 % B767
EA34	+20 % L1011 +20 % DC10	+20 % B747 +40 % DC10 +40 % L1011	+40 % B747 +40 % DC10 +40 % L1011
Business jet	No change	No change	No change
B777	+30 % L1011 +30 % DC10	+60 % L1011 +60 % DC10 +30 % B747	+60 % L1011 +60 % DC10 +60 % B747
Military	No change	No change	No change

The TFG defines 10 regional pairings for flights in the NAT. The traffic forecast for the NAT is sub-grouped into traffic growth for each of the 10 regions. Each origin-destination city pair is assigned to one of the 10 regions classified as shown in Table 4. The TFG provides traffic forecasts for the 10 regions by season (summer and winter).

3.3 Flight Events

Flight data are needed for all flights in order to simulate the air traffic in the NAT. Utilizing the traffic forecasts provided by the TFG and the historical data for the NAT, all the necessary distributions are created to generate the 'flight events' for every 4th and 15th of the month for 1996, 2000, 2005 and 2010.

The number of flights for each simulated day in 1996 matches the number of flights in the historical data for the corresponding day. The percent increases in traffic for the days in 2000, 2005, and 2010 are given by the annual traffic growth TFG forecast. The TFG also provides forecasts for the number of flights by hour interval.

Table 4. Classification of Flight Regions

Region No.	Region Code	Description
1	AFR-NAM/CAR/BER	All of Africa to all of North America, Greenland, Bermuda, and the Caribbean
2	EUR-NAM/EAST	Near or Middle East and all of Europe except Scandinavia and the Iberian Peninsula to Greenland and Eastern US and Canada
3	EUR-NAM/MIDWEST	Near or Middle East and all of Europe except Scandinavia and the Iberian Peninsula to Middle US and Canada
4	EUR-NAM/WEST	Near or Middle East and all of Europe except Scandinavia and the Iberian Peninsula to Western US and Canada
5	EUR/SCAN-CAR/BER	Near or Middle East and all of Europe except the Iberian Peninsula to Bermuda, the Caribbean, South and Central America
6	EUR/SCAN/IBE-NAM/ALASKA	Europe, Scandinavia, and the Iberian Peninsula to Alaska and Hawaii
7	IBE-CAN	Iberian Peninsula to Canada and Greenland
8	IBE-CAR	Iberian Peninsula to the Caribbean, South and Central America
9	IBE-USA/BER	Iberian Peninsula to all of USA and Bermuda
10	SCAN-NAM	Scandinavia to all of North America and Greenland

3.3.1 Statistical Analysis of Historical Data

In this section, we present statistical analysis of the historical data for the air traffic over the NAT airspace for 1996. The data is obtained from NICE-Iceland and Gander OACC, Canada. We use the summaries of the statistical analysis to develop the cumulative distribution functions needed for the generation of flight events.

The statistical analysis begins by determining the frequency of flights among regions. It is followed by the determination of the distribution of flight entry times into the NAT airspace, taking into consideration the proportional increases in the air traffic for years 2000, 2005, and 2010. Similarly, the distribution of the aircraft type takes into consideration the gradual phasing out of several aircraft types and the gradual increase of others. The number of military aircraft in the system is kept constant for all years. The contribution of military aircraft will not be considered in the performance measures of the system, therefore, a fixed aircraft type and related characteristics are assigned to every military aircraft generated in the flight events.

3.3.2 Flight Departure Times

The distribution of the flight departure times depends on the season, direction, and flight region. The summer season starts in May and ends in October, whereas the winter season starts in November and ends in April. Analysis of the 1996 data shows that there were 916 flights for an average summer day, 50.06% eastbound and 49.94% westbound. There were 746 flights for an average winter day, 49.83% eastbound and 50.17% westbound.

Utilizing the TFG forecasts and the historical data, we create the forecast distributions for the 10 regions by season, direction, and hour interval. Table 5 shows the distributions for the 10 regions by season and direction for the 1996 data.

Table 5. Flight Distribution Among Regions

Region Code	Summer East	Summer West	Winter East	Winter West
AFR-NAM/CAR/BER	0.0073	0.0076	0.0078	0.0060
EUR-NAM/EAST	0.5284	0.5297	0.5230	0.5297
EUR-NAM/MIDWEST	0.1544	0.1489	0.1356	0.1340
EUR-NAM/WEST	0.0741	0.0741	0.0744	0.0684
EUR/SCAN-CAR/BER	0.0892	0.0875	0.1190	0.1205
EUR/SCAN/IBE-NAM/ALASKA	0.0093	0.0083	0.0121	0.0089
IBE-CAN	0.0056	0.0052	0.0056	0.0033
IBE-CAR	0.0218	0.0241	0.0217	0.0216
IBE-USA/BER	0.0434	0.0457	0.0424	0.0432
SCAN-NAM	0.0664	0.0718	0.0583	0.0644
Total	1.0000	1.0000	1.0000	1.0000

To include the increase in the air traffic as provided by NAT TFG (Appendixes A and B), we divide every day into 24 one-hour intervals and determine the number of flights that occurred in each interval for each region, direction, and season. We utilize the three forecast values (High, Base, and Low) provided by TFG (Table 6) to estimate the most likely forecast using the mean of a Beta probability distribution given by the following equation:

$$\text{Most likely forecast} = \frac{\text{Low forecast} + 4*\text{Base forecast} + \text{High}}{6}$$

Table 6 shows the forecast of the number of flights for an average day. Years 1996, 2000, 2005, and 2010 are highlighted. The forecasted increases for each season, region, direction, and hour interval are shown in Appendix C.

Table 6. Forecast for the Average Number of Flights per Day

Year	High	Base	Low	Most Likely	Summer[2]	Winter[3]
1996					887	720
1997	6.38	6.38	4.60	6.08	941	764
1998	5.22	5.22	3.42	4.92	987	801
1999	5.00	3.27	2.05	3.36	1020	828
2000	4.70	3.35	2.08	3.36	1055	856
2001	4.49	3.60	2.35	3.54	1092	887
2002	3.93	3.48	2.20	3.34	1129	916
2003	3.08	2.98	1.26	2.71	1159	941
2004	2.98	2.89	1.24	2.63	1190	966
2005	2.90	2.81	1.23	2.56	1220	990
2006	3.03	2.46	0.93	2.16	1248	1013
2007	2.94	2.40	0.92	2.24	1276	1036
2008	2.85	2.34	0.91	2.19	1304	1059
2009	2.77	2.29	0.90	2.14	1332	1081
2010	2.70	2.24	0.89	2.09	1360	1104

[2] Total forecast for year 1996 is 916 (887 civilian +29 military). Military kept constant for all years.
[3] Total forecast for year 1996 is 746 (720 civilian +26 military). Military kept constant for all years.

All the unique origin / destination airport pairings from the historical data are grouped into the appropriate regions. Based on the 1996 data, we create a distribution for the origin / destination airports within each region.

With these distributions in place and given the day and year, the Flight Event Module generates the total number of flights. For each flight, the Flight Event Module assigns a departure time, region number, direction, and origin / destination airports.

3.3.3 Distribution of Aircraft Types

The type of aircraft assigned to a given flight is determined by the region, direction, and season. We modeled 12 aircraft types as described in Table 7.

Table 7. Classification of Aircraft Types

AC Type	Description	AC Type	Description
AC1	B767-300	AC7	MD11
AC2	B747-200	AC8	B757
AC3	DC10	AC9	EA340
AC4	L1011	AC10	Business Jet
AC5	A310	AC11	B777
AC6	B747-400	AC12	Military

Using these classifications and the region classifications described previously, we create cumulative distributions for aircraft type based on region, direction, and season for the 1996 data. For the future years, the distribution of aircraft types is expected to change according to the phasing out of some and the gradual increase of other major aircraft types as described at NICE meeting No. 7 in July 1997. This was described earlier in Table 3.

The AC10 represents a typical business jet as agreed upon by the NICE Task Force. The jet has similar characteristics as a B757, but its take-off weight is about one-fifth of the B757. We refer to this jet as the NICE JET (see Appendix D).

Considering these expected changes, we forecast the distribution of aircraft types for each region, direction, and season for the years 2000, 2005, and 2010. The cumulative distributions for aircraft type by region, direction, and season for 1996, 2000, 2005, and 2010 are shown in Appendix E.

3.3.4 Distribution of Aircraft Speeds

The aircraft speeds are recorded in Mach number as given in the 1996 Gander OACC data. The Mach numbers range from 0.790 to 0.860. Aircraft speed is dependent only on the type of aircraft. Table 8 shows the cumulative distributions of the speeds by aircraft type.

Table 8. Cumulative Distributions of Aircraft Speeds

AC Type	0.790	0.800	0.810	0.820	0.830	0.840	0.850	0.860	Average
B767	0.012	0.737	0.901	1.000					0.80350
B747-200				0.026	0.085	0.792	0.953	1.000	0.84143
DC10		0.121	0.280	0.503	0.878	1.000			0.82218
L1011				0.047	0.721	1.000			0.83231
EA31	0.038	0.564	0.946	1.000					0.80452
B74F						0.063	0.612	1.000	0.85325
MD11				0.251	0.735	1.000			0.83014
B757	0.098	0.929	1.000						0.79973
EA34			0.178	0.593	1.000				0.82228
NICE-Jet[4]	0.098	0.929	1.000						0.79973
B777					0.075	0.929	1.000		0.83996

3.3.5 Distribution of Take-off Weights

We obtain data for take-off weights from Lufthansa, Air Canada, British Airways, Trans World Airlines, and American Airlines for year 1996. After analyzing the data, we determine that take-off weight is dependent on aircraft type and region and can be approximated by a triangular distribution. Table 9 shows the most likely (average) take-off weights for the aircraft types and regions.

Table 9. Average Take-off Weight Values (in Pounds)

Region #	B767	B747-200	DC10	B74F	MD11	EA34
1						
2	334068	686380	487922		501148	492628
3	334513	689686	543821	767156	540217	473133
4	359094	724098		771977		496328
5		729686	524302	801037		
8	363539	665001				
9	373468					
10	387000	766250	542000	822500	585750	534500

Data are not available for all aircraft types and regions; therefore, we estimate the most likely take-off weights. For regions where data are provided for some aircraft types but not others, we found the percent of the maximum value for the most likely take-off weights of the data. We then use a weighted average based on the number of data points obtained for each aircraft type in the region to obtain the average percent of the maximum value. We multiply this percent in each

[4] Because the NICE-JET (business jets) considers many different models, the range of speeds is quite large. To simplify, we model the NICE-JET as a B757. Appendix D shows a comparison of speeds and flight levels for the B757 and the NICE-JET

region by the maximum take-off weight for each aircraft (whose take-off weight data are not provided) to obtain an estimate of the most likely take-off weight.

Because we are assuming a triangular distribution, we also need the maximum and the minimum take-off weights. For the maximum take-off weights, we use the values given in *Jane's All the World's Aircraft (1996-1997)* [7]. For the minimum take-off weights, we found the lowest take-off weight value for each region and aircraft type and computed it as a percentage of the maximum take-off weight for that aircraft type. We use a weighted average across aircraft types for each region to obtain an average percent of the maximum value for the minimum take-off weight. We then multiply this percentage for each region by the maximum take-off weight for each aircraft type to obtain the minimum take-off weight for each region and aircraft type. Because there are no data for any aircraft types in region 6 and 7, we estimate the percent of maximum value for the minimum and most likely cases based on the percentages for other regions with the same approximate travel distance.

Table 10 shows the take-off weight distributions for select aircraft types across all regions. The take-off weight distributions for all regions and aircraft types are shown in Appendix F. For the values based on 1996 data, most likely take-off weights are rounded to the nearest one. For the values based on computations, take-off weights are rounded to the nearest thousand.

Table 10. Sample Take-off Weight Distributions

	B767			**B747-200**		
Region	**Min**	**Likely**	**Max**	**Min**	**Likely**	**Max**
1	377000	392139	418000	754000	784000	820000
2	268000	334068	418000	535000	686380	820000
3	279000	334513	418000	560000	689686	820000
4	318000	359094	418000	636000	724098	820000
5	311000	368000	418000	622000	729686	820000
6	356000	387000	418000	712500	766250	820000
7	287000	349000	418000	574000	697000	820000
8	303000	357000	418000	609000	713000	820000
9	324000	363539	418000	649000	665000	820000
10	335000	373468	418000	671000	734000	820000

3.3.6 Payload Distribution

NICE-ICE performed the statistical analysis of data obtained from the same airline companies that provided the take-off weight, and the results are graphically summarized as shown in Figures 3 through 6. We obtain information from these figures in order to develop the cumulative distribution functions of the payload for the four seasons.

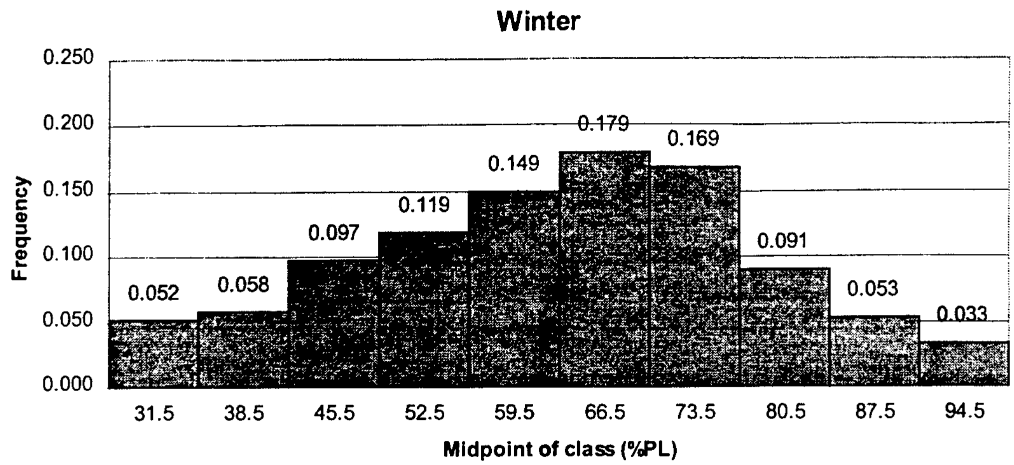


Figure 3. Winter payload distribution.

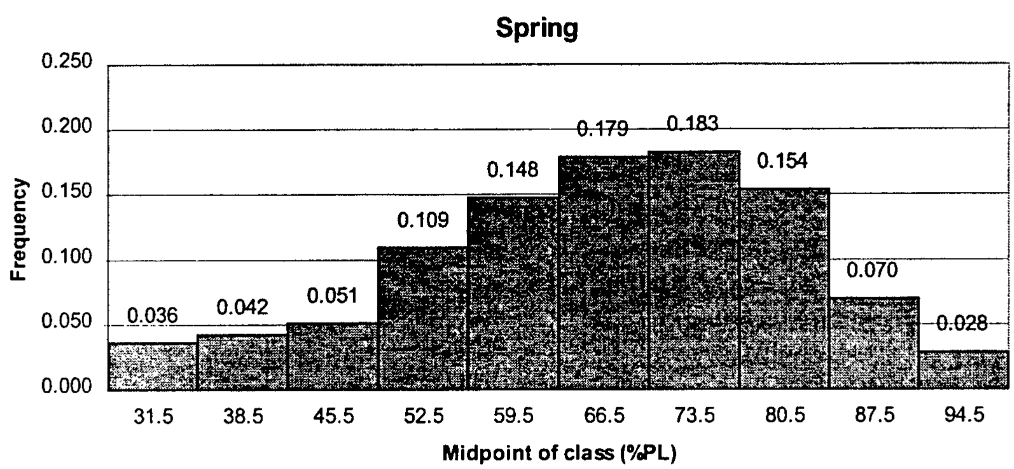


Figure 4. Spring payload distribution.

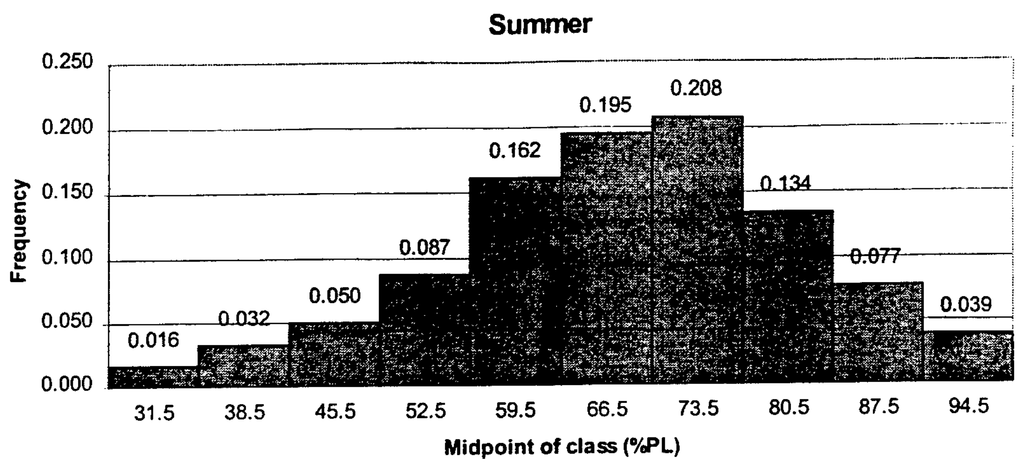


Figure 5. Summer payload distribution.

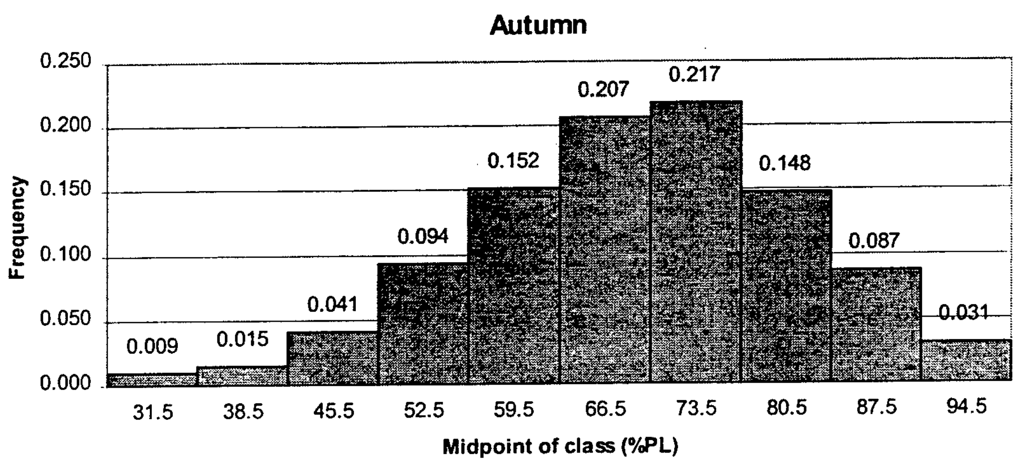


Figure 6. Autumn payload distribution.

3.3.7 Generation of Flight Events

The Flight Event Module is written using Arena version 2.1. Arena is an object-oriented simulation language that uses blocks representing a function or subroutine. When arranged and linked according to the logic of the system to be simulated, they form a complete program. The module is used for flight events for years 1996, 2000, 2005, and 2010 using the distributions presented in the previous sections.

3.3.8 Report of Flight Events

The simulation program generates 12 separate reports. The summer routine writes to files labeled as the 4th and 15th of May, June, July, August, September, and October. The winter

routine writes to files labeled as the 4th and 15th of November, December, January, February, March, and April. Each flight contains 10 fields; day, departure time, region, direction, origin, destination, aircraft type, civilian / military, take-off-weight, and percent payload, respectively.

Departure times run from zero to 1440 minutes and indicate when the flight entered the NAT airspace. Regions are assigned alphabetically and number from 1 through 10, as indicated in Table 11.

Table 11. Region Designation

Region	Abbreviation	Number
AFR-NAM/CAR/BER	ANCB	1
EUR-NAM/EAST	ENE	2
EUR-NAM/MIDWEST	ENM	3
EUR-NAM/WEST	ENW	4
EUR-SCAN-CAR/BER	ESCB	5
EUR/SCAN/IBE-NAM/ALASKA	ESINA	6
IBE-CAN	ICN	7
IBE-CAR	ICR	8
IBE-USA/BER	IUB	9
SCAN-NAM	SN	10

The Flight Event Module assigns indicator values for the direction, day, and civilian/military fields. Table 12 presents these indicator values. Direction is designated as zero for eastbound and 1 for westbound. Day is designated as zero for day N-1 and 1 for day N. Day N-1 indicates the aircraft has a departure time occurring on the day before the simulated day, N, with reference to midnight at longitude 20 W. The civilian / military indicator is designated as zero for civilian flights and 1 for military flights.

Table 12. Direction, Day and Civilian / Military designation

Direction	Day	Civilian / Military	Number
East	N-1	Civilian	**0**
West	N	Military	**1**

Origin-destination is an integer value unique to the city pair. An additional program matches the number corresponding to city pairs to International Civil Aviation Organization (ICAO) code. Aircraft type is an integer from 1 through 12 as shown in Table 13.

Table 13. Aircraft Type Designation

AC Type	Number
B767-300	1
B747-200	2
DC10	3
L1011	4
A310	5
B747-400	6
MD11	7
B757	8
EA340	9
B Jet	10
B777	11
Military	12

The simulated data for January 4th, representing a typical winter day in 2005, are included in Appendix G. A partial listing of this appendix is given in Table 14.

Table 14. Partial Listing of the Flight Events for January 4, 2005

Day	NAT Entry Time	Region Designation	Direction Designator	Origin Airport ICAO Code	Destination Airport ICAO Code	Aircraft Type Code	Civilian/ Military Designator	Cruise Mach (*1000)	Take-Off Weight (lbs)
0	1437	9	0	KJFK	UUEE	1	0	800	379414
0	1438	2	0	KATL	EDDM	10	0	800	37863
0	1438	2	0	KEWR	LFPO	2	0	840	767753
0	1438	4	0	CYVR	EGLL	6	0	850	737907
0	1439	3	0	CYYZ	LFPG	11	0	840	454796
0	1439	5	0	MDSD	LFPG	1	0	820	371165
1	1	2	0	KCVG	EGKK	1	0	800	375227
1	1	2	0	KJFK	LFPO	9	0	820	487548
1	1	2	0	KMIA	EDDF	1	0	800	294230
1	2	3	0	KORD	EGCC	1	0	800	350401
1	4	2	0	KIAD	EGLL	11	0	840	511093
1	5	2	0	KJFK	EGLL	2	0	840	696262
1	5	5	0	MUVR	LFPO	2	0	850	729083
1	5	8	0	KJFK	LPPT	1	0	800	386389
1	6	2	0	KJFK	EHAM	10	0	800	37161
1	6	3	0	CYYZ	EGPF	1	0	800	370129
1	8	4	0	KLAX	LSZH	6	0	850	750467

3.3.9 Verification of Flight Event Generation

In this section, we discuss the verification of the flight event generation program. This includes descriptions of the verification methods used to determine expected values and a sample of the verification results. The complete verification results are shown in Appendix H.

3.3.9.1 Verification Descriptions

To verify the flight event generation programs, we compare expected values of flight event variables with the generated values for years 1996, 2000, 2005, and 2010. The variables that we considered are

a. the number of flight events within each region by direction and season;

b. the number of flight events within each hour interval by region, season, and direction;

c. the number of flight events for each aircraft type by region, direction, and season;

d. the average speed of the aircraft by aircraft type;

e. the average take-off weight of the aircraft by aircraft type and region; and

f. the percent payload distribution by payload season.

Although the speed and take-off weight values are not dependent on the season, we verify these variables by region to ensure that generated flight events were valid for each year and season.

3.3.9.2 Calculation of Expected Values

Our expected values for the number of flights by region, direction, and season and the number of flights by hour interval, region, direction, and season are based on the air traffic forecast as discussed earlier and shown in Appendixes A and B. We also use these values to forecast the expected number of aircraft types by region, direction, and season. Using the aircraft type distributions as discussed earlier and shown in Appendix C, we multiply the expected number of flight events by the probability values of aircraft types for each region for a given direction, season, and year to obtain the expected number of flights for each aircraft type by region, direction, season, and year. Because the speed, take-off weight, and percent payload distributions are not expected to change over the years, we use the expected values calculated from the statistical analysis of 1996 data.

3.3.9.3 Sample Verifications

A complete summary of all verification performed is shown in Appendix H. Table 15 shows the expected number of flights and the number generated from simulation for each season and year.

Figure 7 shows a comparison of the generated and the expected number of flights by region for an average winter day, eastbound, in 2000. The number of flights generated is very close to the number expected for all regions in each year.

Table 15. Expected vs. Generated Number of Civilian Flights

Season	Expected (Exp)	Generated (Sim)
Summer 1996	887	888
Summer 2000	1055	1053
Summer 2005	1220	1218
Summer 2010	1360	1349
Winter 1996	720	721
Winter 2000	856	867
Winter 2005	990	995
Winter 2010	1104	1107

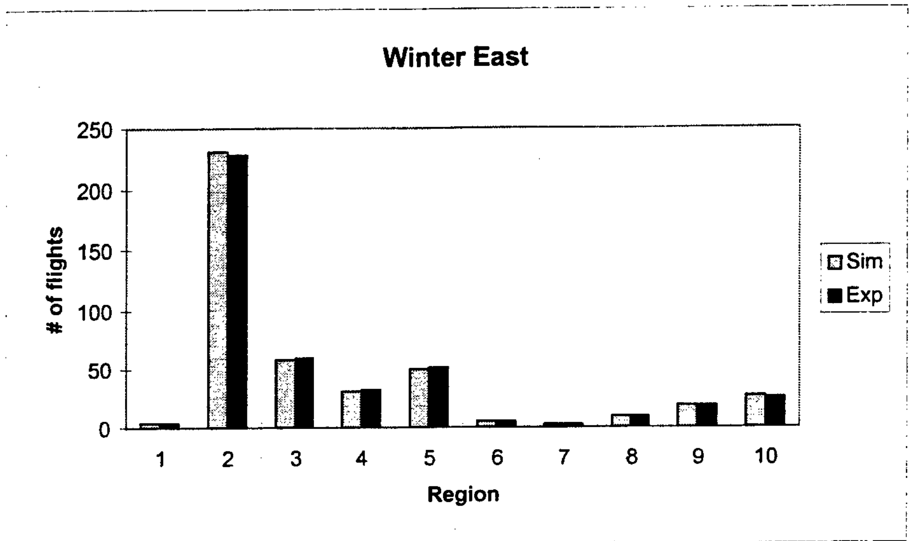


Figure 7. Number of flights-per-day by region for winter eastbound 2000.

Distribution of Aircraft Types

The number of flights by region for each aircraft type depends not only on the growth in traffic for that region but also on the change in the distribution of aircraft types. This is because new aircraft types become more prevalent while others are phased out. Figures 8 through 11 show the comparison in the number of flights for aircraft type 2, B747-200, by region, for summer eastbound years 1996, 2000, 2005, and 2010, respectively. The increase in the number of flights for each region from 1996 to 2000 is due to the increase in traffic. The decrease in the number of flights for each region from 2000 to 2005 is due to the gradual phase out of the B747-200, where 30% of the flights previously using B747-200 use B777 (aircraft type 11) and 20% use A340 (aircraft type 9). By 2010, the phase out is complete, and regions are not using B747-200.

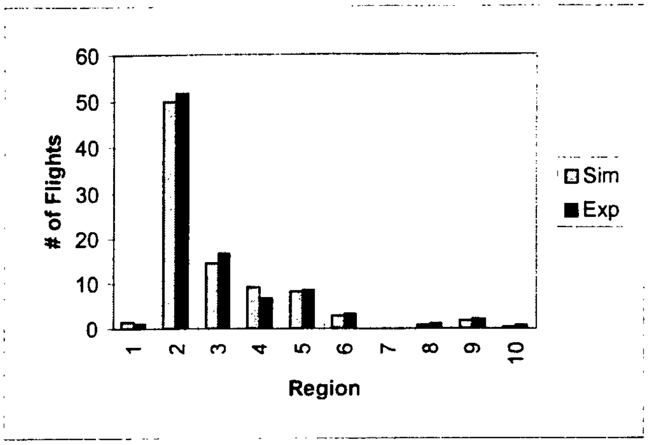


Figure 8. B747 A/C 1996, summer, east.

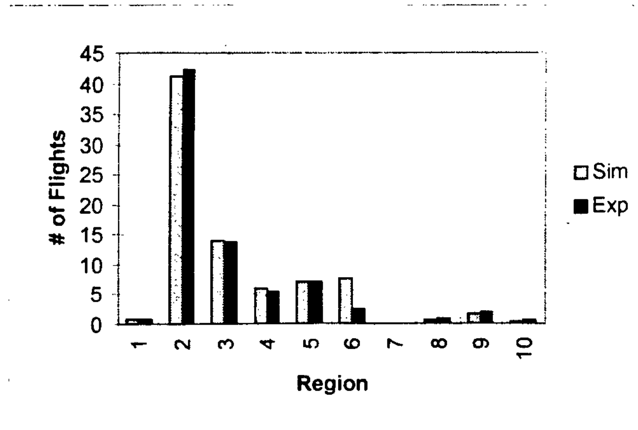


Figure 9. B747 A/C 2000, summer, east.

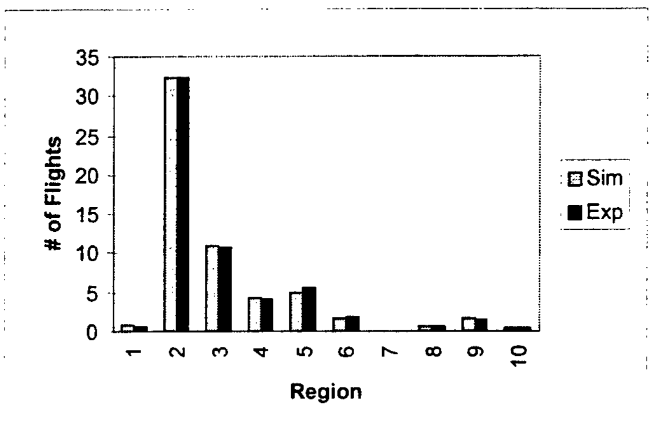


Figure 10. B747 A/C 2005, summer, east.

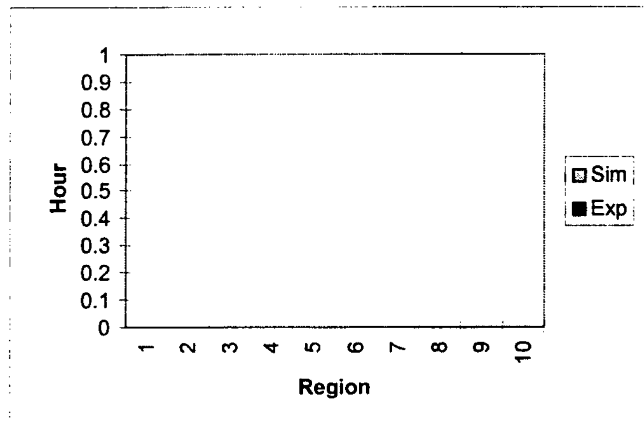


Figure 11. B747 A/C 2010, summer, east.

Distribution of Aircraft Speeds

Figure 12 shows the speeds by aircraft type for summer 2005. There is minimal difference between the expected average speed and the generated average speed due to the large number of flights being averaged. Because the speed distribution depends only on aircraft type and not on the number of flights, there is no difference from year to year. However, as certain aircraft types are phased out, their speed distributions are no longer used. In 2005, there are no aircraft type 3 (DC10), type 4 (L101), type 5 (A310), or type 8 (B757). Types 3 and 4 are replaced 60% by type 11 (B777) and 40% by type 9 (A340). Type 12 (B767-300) replaces types 5 and 8.

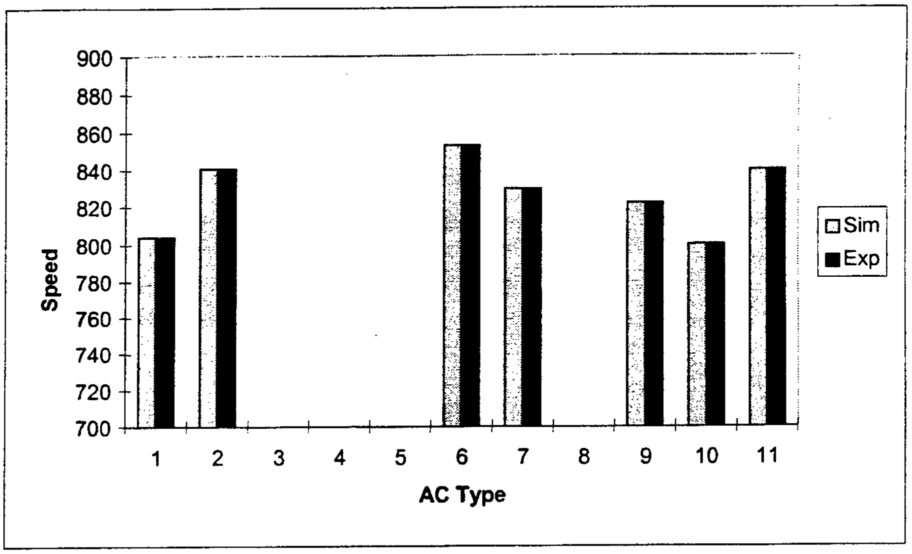


Figure 12. Speed by aircraft type for summer, 2005.

Distribution of Take-off Weights

Take-off weights are only dependent on the aircraft type and region. Therefore, the distribution of take-off weight does not change from year to year. Figure 13 shows the take-off weights by region for aircraft type 1 (B767-300) for summer 2000. In this season, the greatest difference between the expected and the generated average take-off weight is about 8,600 pounds or 2.58% of the expected weight. For all years, regions, and aircraft types, the greatest difference between the expected and generated average take-off weights is 9% of the expected, whereas on average, the difference is about 1.6% of the expected, with the greater differences occurring for regions with small numbers of flight events.

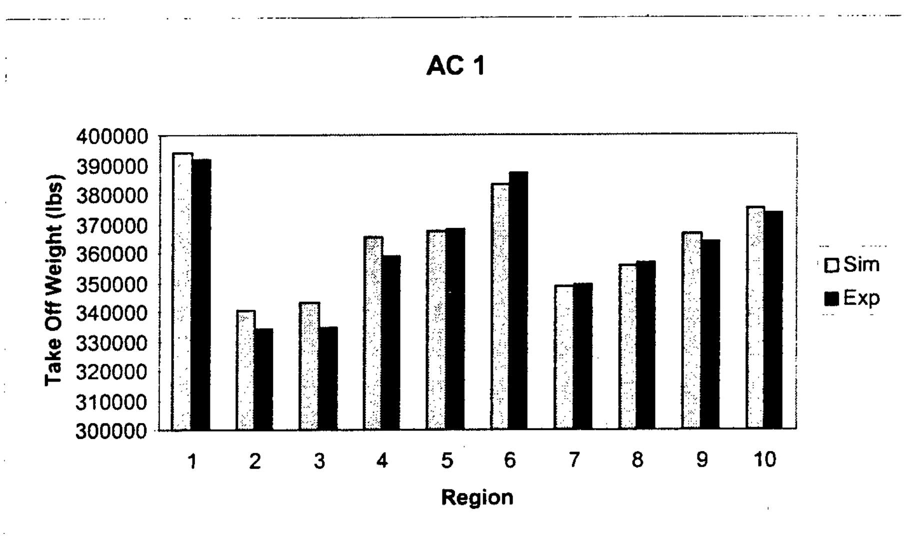


Figure 13. B767 take-off weight distribution for summer, 2000.

Distribution of Payload

Payload distribution depends only on the season (winter, spring, summer, or autumn). Therefore, similar to the speed and take-off weight distributions, the payload distribution does not change from year to year. Figures 14 through 17 show the percent payload distributions for winter, spring, summer, and autumn 2010, respectively. They are compared based on the fraction of the total number of flights for each of the 10 payload categories.

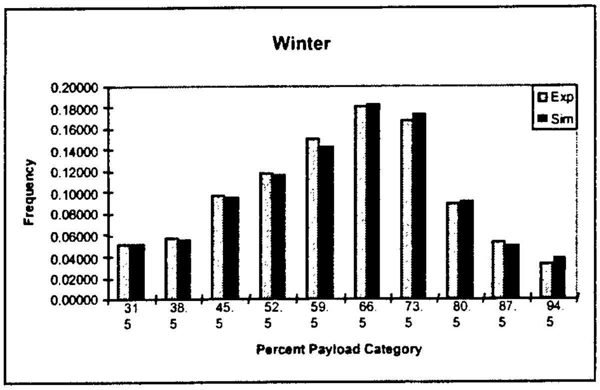


Figure 14. Percent payload distribution for winter, 2010.

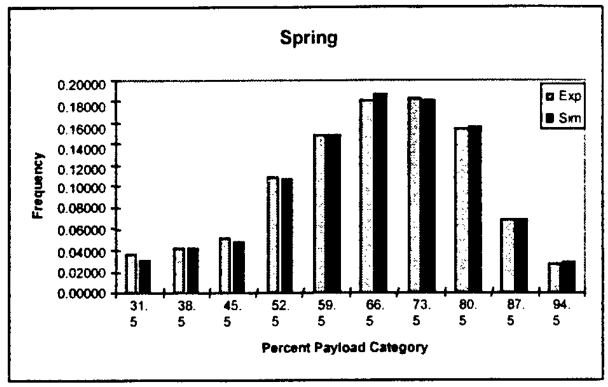


Figure 15. Percent payload distribution for spring, 2010.

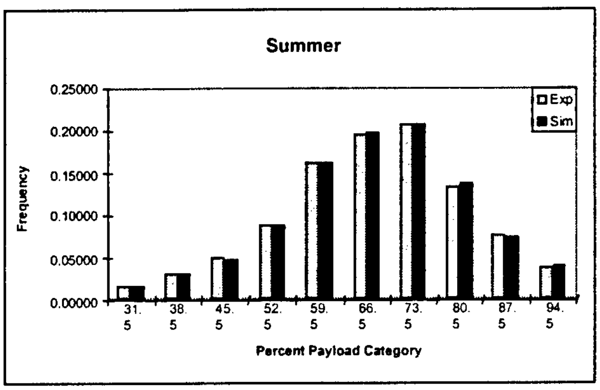


Figure 16. Percent payload distribution for summer, 2010.

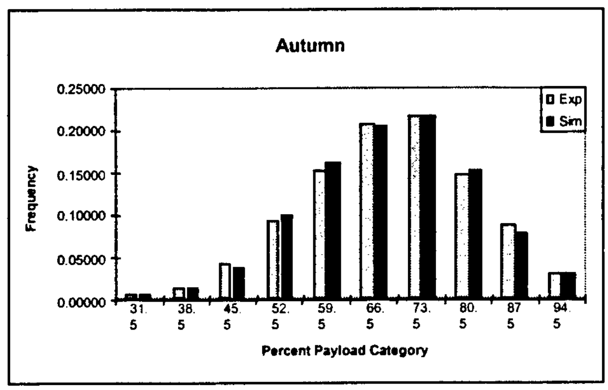


Figure 17. Percent payload distribution for autumn, 2010.

3.4 Meteorological Data

The UK Meteorological (MET) Office supplies the weather data for this study. For each day N, the following MET data were obtained (F=Forecasted weather, A=Actual weather):

- F0: F-18H-0000(N-1) (18-Hour forecast generated at 0000 on day N-1)
- F1: F-12H-1200(N-1) (12-Hour forecast generated at 1200 on day N-1)
- F2: F-18H-1200(N-1) (18-Hour forecast generated at 1200 on day N-1)
- F3: F-12H-0000(N) (12-Hour forecast generated at 0000 on day N)
- F4: F-18H-0000(N) (18-Hour forecast generated at 0000 on day N)

- F5: F-12H-1200(N) (12-Hour forecast generated at 1200 on day N)
- A0: A-1800-(N-1) (analysis at 1800 on day N-1)
- A1: A-0000-(N) (analysis at 0000 on day N)
- A2: A-0600-(N) (analysis at 0600 on day N)
- A3: A-1200-(N) (analysis at 1200 on day N)
- A4: A-1800-(N) (analysis at 1800 on day N)
- A5: A-2400-(N) (analysis at 2400 on day N = analysis at 0000 on day N+1)

The usage of the MET data is shown in the Figure 18. We use interpolation to determine the MET conditions at clock times between the 6-hour files times (e.g., the forecasts between 0000 and 0600 on day N use an interpolation between F1 and F2, likewise the analyzed data between 0000 and 0600 on day N use an interpolation between A1 and A2).

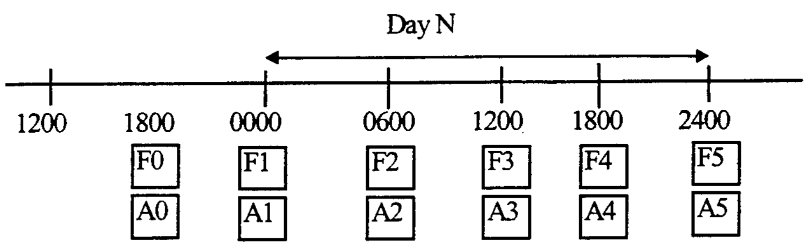


Figure 18. Usage of the MET data.

The UK MET Office provides wind information at five flight levels: 24,000 ft, 30,000 ft, 34,000 ft, 39,000 ft, and 45,000 ft. The longitude spacing of the data is 1.25 degrees, and the latitude spacing is 0.833 degrees. Wind information for points between the grid structures is interpolated. Two wind components are supplied for each grid point, a westerly and southerly wind component. These component wind data are converted to wind magnitude and direction before used in the model. Temperatures are not provided in the MET data files; therefore, we use the standard temperature model.

3.5 Organized Track System

The NAT air traffic flow adjusts to the changing weather. Due to the significant easterly winds that are present, the bulk of the eastbound traffic prefers to travel with the Jet Stream utilizing the tail winds. The westbound traffic prefers to avoid the Jet Stream. To allow as many aircraft as possible to obtain their optimal flight path and to aid in the tasks performed by the ATC, an OTS is established every day. This track system defines the "highways in the sky" running from Europe to North America, which provide the corridors to be used by the main traffic flows. Using MET forecasts, the OTS planners place the eastbound OTS on specific latitudes so the majority of the eastbound traffic can take advantage of the significant winds. The westbound OTS is placed on specific latitudes so the majority of the westbound traffic will avoid the headwinds.

The major OTS placement variations occur due to the changing wind patterns and intensities. The eastbound track structure will always be placed within the most significant winds. The westbound OTS structure is more complex. There are three typical westbound track structures that take place; the north-about OTS system, the great circle OTS system, and the south-about OTS system.

The westbound OTS is placed north of the Jet Stream in the north-about OTS system. When the high intensity winds flow south of the 50 degree north latitude, the westbound OTS are positioned so that the traffic enters the NAT north of Ireland and exits the NAT north of Newfoundland.

The great circle OTS system positions the westbound and eastbound in close proximity to each other. This system occurs when the winds are light. The resulting track structure is one that resembles the shortest geographical routes (or Minimum Time Tracks - MTT) from North America to Europe. This system requires coordination between the Gander and Shanwick OACCs because opposite direction traffic may be competing for the same tracks.

The south-about OTS system occurs when the significant winds are located north of Newfoundland. The westbound traffic enters the NAT south of Ireland and exits south of Newfoundland. This system complicates the coordination required by the OACCs because now, not only are the Gander and Shanwick OACCs required to coordinate change over periods for the eastbound to the westbound traffic flow, the New York and Santa Maria OACCs must be included in the OTS communication. Therefore, this system requires major coordination between four of the five OACCs.

An example of an actual eastbound and westbound OTS placement for July 15, 1995 is shown in Figure 19. From this figure, one can infer that the significant winds were located south of the 50 degree north latitude. Figure 19 demonstrates a typical north-about OTS system for the westbound OTS. The eastbound OTS is placed within the Jet Stream to take advantage of the tail winds.

The eastbound OTS is established everyday by the Gander OACC. The system used is called the Gander Automated Air Traffic System (GAATS). GAATS is supplied with weather forecasts twice each day by the United States National Weather Service (NWS) in Suitland, MD. The weather data contain the wind speed, direction, and temperature for various pressure levels usually including at least the 400, 300, 250, and 150 mbar pressure levels. Each forecast includes four separate projections at 6-hour intervals beginning at 0600 Greenwich Mean Time (GMT) or 1800 GMT. GAATS finds the MTT for the New York to London route. The planner will identify a few additional MTTs of importance based on information received from the day's preferred track messages. The preferred track messages are received from the airlines and identify the tracks desired between certain North American and European airports calculated by the airlines assuming no system constraints.

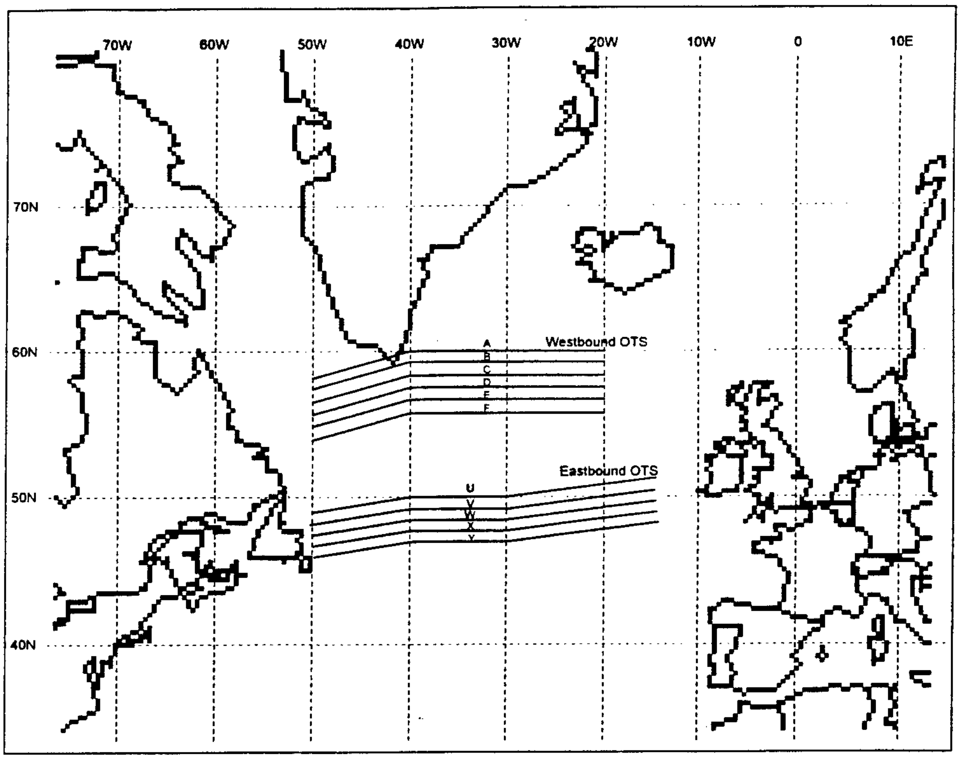


Figure 19. July 15, 1995 OTS placement.

The Shanwick OACC establishes the westbound OTS every day. The establishment of the westbound OTS is not as simple as the eastbound establishment; there is not an automatic system in place similar to GAATS. The Shanwick OTS planners receive weather forecasts from the Bracknell Meteorological Office in the United Kingdom. The planners use the 250 mbar pressure level to graphically evaluate the westbound MTT situation. The MTT route from London to New York is manually plotted using this information. As in the eastbound OTS establishment, the OACC receives preferred track messages. These messages are then used in this manual process to establish the complete westbound OTS.

The OTS for every 4th and 15th day in 1996 are collected. The future OTS for 2000, 2005, and 2010 are estimated by NICE-ICE with assistance from experienced air traffic operational planners using the weather data from 1996.

3.6 Aircraft Performance and Fuel Data

Lido GmbH, Lufthansa Aeronautical Services, provides aircraft performance data specific for aircraft operations in the NAT. They provide the performance data and fuel calculation information for 10 aircraft types.

The miscellaneous jet category utilizes the B757-200 fuel and performance information. The performance data provides information for several phases of flight: ascent, descent, holding, en route, and emergency. Three of these phases are used in the model: ascent, descent, and cruise.

The performance data are specific to each phase of flight for each aircraft. The data provided included the following:

a. Lowest flight level in range
b. Normal true airspeed
c. Maximum allowable true airspeed
d. Normal acceleration / deceleration
e. Normal bank angle
f. Normal climb rate
g. Normal descent rate

Lido creates an aircraft performance data file for each aircraft type. When necessary, we retrieve these values during simulation.

Lido also provides aircraft fuel data specific for aircraft operations in the NAT. These data provide the aircraft fuel rate dependent on the aircraft type, speed, current flight level, and current weight of the aircraft.

4. Model description

4.1 Overall Framework of the Simulation Model

The NICE-USA Task Group calls the simulation model the Integrated North Atlantic Air Traffic Simulation Model (INATSIM). INATSIM is developed in a modular structure to simplify its expansion and modification in the future. The model utilizes an upper level simulation language for the modeling of aircraft and conflict detection. This computer language, called General Purpose Simulation Language (GPSS/H) by Wolverine Software (Version CT185), internally tracks aircraft movements through the system. We use other programs such as ARENA, FORTRAN, and Proof Animation for intensive calculations, data manipulation, and graphical animation. Figure 20 summarizes the structure of the model.

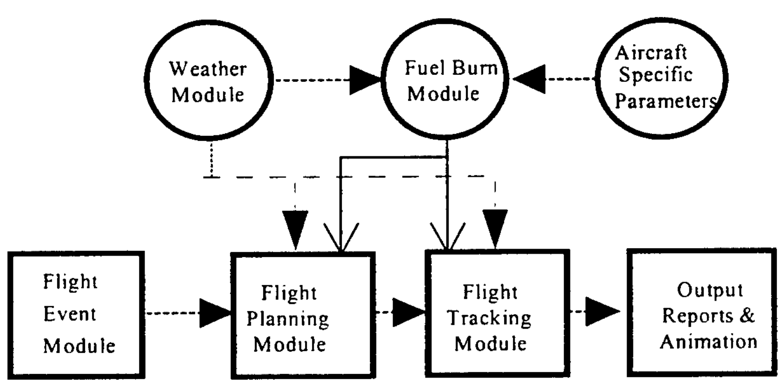


Figure 20. Framework of INATSIM.

The Flight Event Module generates the stochastic input data that drive the system. The data include the origin and destination airports, direction, aircraft type, take-off weight, speed, the departure times from the origin airport, payload of the aircraft, and other information such as the coordinates of the airport locations. The two main modules are the FPM and the FTM. The FPM uses the flight events and generates the optimal flight path that minimizes the total fuel consumption for each aircraft in the flight events input file. The FTM actually tracks the NAT crossings and performs the ATC tasks. The Weather module provides winds and temperatures aloft to the Flight Planning, Flight Tracking, and Fuel Burn modules. The Fuel Burn module performs extensive calculations for obtaining the estimated fuel consumed for each flight. The simulation output is obtained in several forms. The computer animation and various system statistics are provided as output of the simulation. In the following sections, we briefly describe details of the modules of the INATSIM.

4.2 Flight Event Module

An average of 800 flights crossed the NAT MNPS airspace daily in 1996. These flights originated from hundreds of airports mainly located in the upper hemisphere.

The TFG provides traffic forecasts for the NAT airspace. These include forecasts for the years 2000, 2005, and 2010. They provide such forecasts as the percentage increase in total traffic by season (winter and summer), percentage of directional traffic per hour by season, and percentage of traffic by regional pairing. The NAT regions and aircraft type distributions are described in Section 3 of this report.

In order to generate a representative set of flight events for a day, the relationships between the flight attributes must be satisfied. To develop the Flight Event Module, the TFG forecasts and historical data are utilized to generate probability distributions for these relationships.

The year, day, and season are predetermined before the Flight Event Module begins. The day chosen determines the season. The initial distribution determines the number of flights for the day given the year and season. The necessary relationships are shown in Figure 21. The arrows indicate the dependence of the top attribute to the next one. The flow chart order in Figure 21 represents the sequence of the processing in the Flight Event module.

Section 3, Requirements, provides more details about the sources of data and probability distributions. The output from the Flight Events Module is utilized in the FPM.

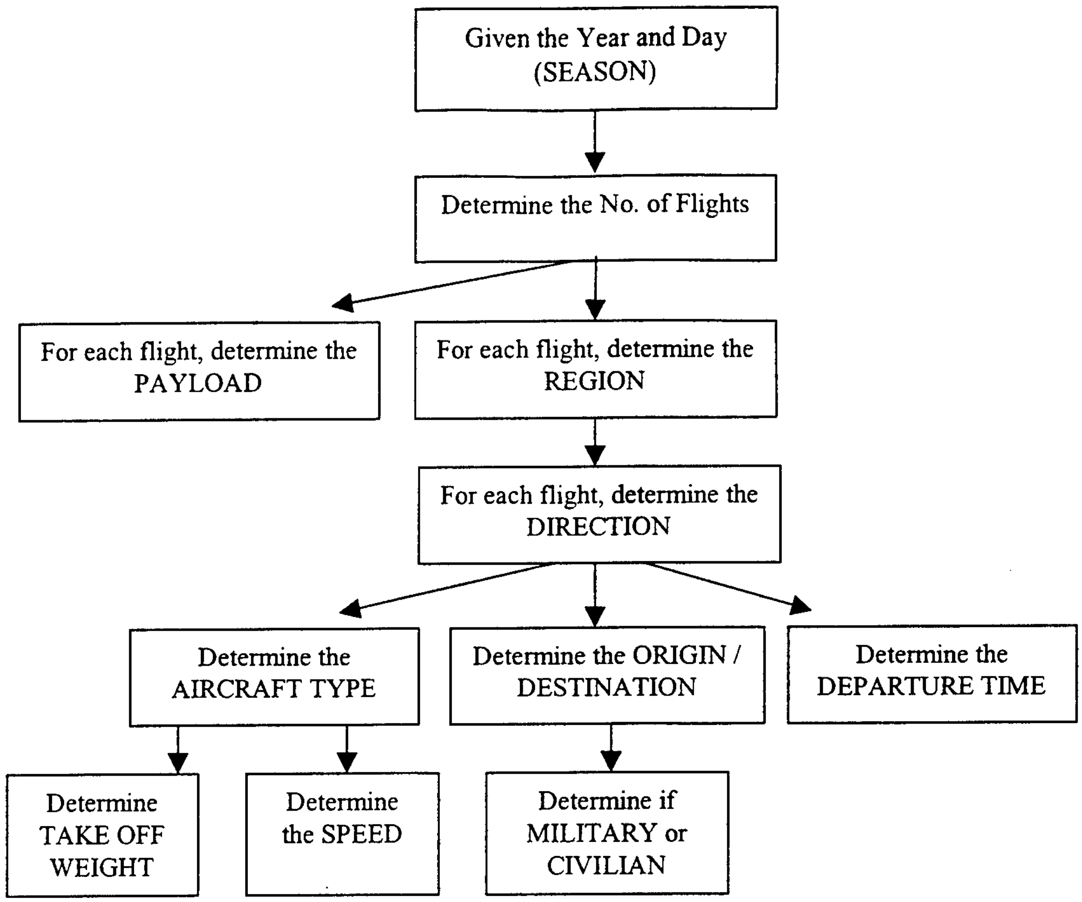


Figure 21. Sequence of flight event generation.

4.3 The Flight Planning Module

The FPM is an optimization model, using a forward dynamic programming search algorithm to determine the optimum flight plan for each flight. In the real systems, air carriers use flight planning to predict fuel burn profiles with forecast weather data and historical data of the particular aircraft. The optimal flight path for each aircraft is estimated for the given origin destination combination, aircraft type, and cruising speed. To determine the optimal flight path of an aircraft that minimizes fuel consumption, the module calculates

a. the aircraft flight path given the meteorological conditions and aircraft specific performance information, and

b. the aircraft fuel consumption as it moves along the flight path.

The FPM utilizes the fuel consumption estimates by searching for the path that uses the minimum fuel. To accomplish the search efficiently, the FPM applies a refined version of dynamic programming with various smoothing and performance constraints.

Before the two-dimensional iterative procedure begins, all the longitudes to be crossed during the flight are defined, based on the location of the origin and destination airports. The maximum number of longitude crossings is 8, which include the oceanic entry and exit points, 60W, 50W,

40W, 30W, 20W and 15W. Each flight plan must provide the oceanic entry and exit points for the aircraft. These entry and exit points are fixed latitude longitude points, which lie on the boundary of the NAT airspace. When an aircraft crosses one of these points, it is considered to be officially entering or exiting the NAT airspace. During the first iteration of the flight plan generation routine, the altitude is held constant at 33,000 ft. Once the aircraft reaches the destination airport, the latitudes computed for crossing the NAT at 33,000 ft are known. During the second iteration through the flight planning routine, the latitudes from the first iteration are held constant, and the algorithm searches for the optimal flight levels at these latitudes. During the third iteration, the altitudes from the second iteration are held constant, and the algorithm searches for the optimal latitudes at the given flight levels. The motivation for using the two-dimensional iterative procedure is the computer processing time that is required to perform a three-dimensional search for aircraft.

The oceanic entry point is not predefined, therefore all feasible entry points are considered. The oceanic exit point is determined when the aircraft reaches the end of its crossing; a feasible exit point must be within three degrees of latitude from its last crossing point.

The refined dynamic programming technique utilizes the Fuel Burn Module. Extensive calculations are required to determine the fuel burn profile for each flight. The algorithm is restricted to specific search ranges in order to minimize computer processing time. The following list represents the restrictions:

- Maximum lateral movement between nodes is 4 degrees.
- Maximum vertical climb between nodes is 5000 ft.
- Flights are not permitted to ascend at the last node (no step climb at last waypoint crossing).
- Lateral restrictions are imposed for special flights. For example, a flight with a North America origin and Iceland destination is not permitted to obtain low latitudes (e.g., below 50 north) during its crossing. Other special flights include Europe or North America to the Santa Maria Islands and Europe to Iceland.

In addition to these restrictions, there are flight level restrictions imposed on specific aircraft types. The data analysis, which aided in the development of the restrictions, is shown in Appendix I. Table 16 shows the list of restrictions by aircraft type.

4.3.1 Track Designation Routine

The output from the FPM is the input into the Track Designation Routine. This routine uses the OTS for the simulation day and the optimal flight paths produced by the FPM. The purpose of the Track Designation Routine is to assign the flights to the OTS. Several criteria must be met for a flight to be designated as an OTS flight. A flight must satisfy all of the following requirements to operate on the OTS:

Table 16. FPM Restrictions by Aircraft Type

Aircraft	Restrictions
B767	None
B747	Not permitted above 37,000 ft during the first few nodes
	Not permitted to reach 41,000 ft
DC10	Westbound not permitted to reach 37,000 ft
	Eastbound not permitted above 37,000 ft during the first few nodes
	Eastbound not permitted to reach 39,000 ft
L1011	Not permitted above 37,000 ft during the first few nodes
	Not permitted to reach 39,000 ft
EA31	Not permitted to reach 39,000 ft
B74F	Not permitted to reach 37,000 ft during first few nodes
	Westbound not permitted to reach 39,000 ft
	Eastbound not permitted to reach 41,000 ft
MD11	Not permitted above 37,000 ft during the first few nodes
	Not permitted to reach 39,000 ft
B757	Not permitted to reach 41,000 ft
EA34	Not permitted above 37,000 ft during the first few nodes
	Not permitted to reach 41,000 ft
B777	None
Misc. Jets	None

- The flight must enter the NAT within the OTS definition period. For eastbound flights, the time period is 01:00 – 08:00 GMT. For westbound flights, the time period is 11:30 – 19:00 GMT.

- The flight must be able to operate on the entire OTS. The longitudes (at the waypoints) defined in the OTS must be contained in the flight plan. An OTS flight cannot leave a designated track early. This requirement is a function of the origin and destination airports (e.g., a flight leaving a North America airport with an Iceland destination will not be designated as an OTS flight).

- A minimum lateral distance (set by the user) from the OTS must not be exceeded. This constraint helps to eliminate flights operating north or south of the OTS from consideration for the OTS. It also identifies the best OTS track for flights operating within the OTS. The lateral differences at 50W and 20W are computed between the flight plan and each track on the OTS. The lateral differences at both 50W and 20W must be less than or equal to the minimum lateral distance to be considered for the OTS.

If a flight is determined to operate on the OTS, its flight plan is modified to match the track definition exactly. The waypoints and the entry and exit points will match those defined for the track chosen. The flight levels remain as they are in the original flight plan. A track code is assigned to the flight representing the OTS track chosen. Letters A-H are reserved for the westbound OTS. Letters S-Z are reserved for the eastbound OTS. A letter is predefined for each track in each day's OTS definition.

The original flight plan is kept in tact for Random flights (non-OTS). The latitudes at 50W and 20W are again observed, this time to determine whether the flight is operating north, south, or within the OTS. A designator of RN (Random North), RS (Random South), or RI (Random Internal) is assigned to all Random flights.

A RI flight may operate on one of the OTS tracks for a few waypoints, but it will not stay on the track for the entire crossing. It will divert into the airspace north of the OTS, south of the OTS, or onto another OTS track. Another possibility for the flight is to enter the NAT either north or south of the OTS (during the crossing, it gradually moves toward the OTS). Eventually, the flight will join the OTS during the last few waypoints. Although the flight operates on the OTS for some time, it does not operate on the OTS for the entire crossing and therefore is labeled as Random.

4.4 The Flight Tracking Module

The FTM performs the function of the OACC by tracking the aircraft across the NAT. It utilizes the optimal flight plans under the constraints of the OTS, MET conditions, and the ATC reclearance rules to obtain the ATC separated flight plans.

The FTM relies on several supporting routines such as the MET module and the Fuel Burn module. These supporting routines, the aircraft specific parameters, and the conflict detection and resolution algorithms are the core elements of the FTM. The following steps refer to the sequential process of FTM and provide a brief overview of the core elements within the FTM.

a. The FTM generates the flights with their attributes previously defined in the flight plan file. The attributes include a unique flight code number, direction code, track identifier (OTS or Random), cruising Mach speed, departure time, entry time, take-off weight, origin and destination coordinates, and the flight plan. The flight plan consists of the latitude, longitude, and flight level at the oceanic entry and exit points and the latitudes and flight levels at 60W, 50W, 40W, 30W, 20W, and 15W.

b. Following the initialization of the other aircraft attributes, track codes are also assigned using the OTS coordinates defined in the Track Designation Routine. The OTS consists of the latitudes and longitudes of each track specific-oceanic entry and exit points and the latitudes at 60W, 50W, 40W, 30W, 20W, and 15W. Each track is assigned a specific range of flight levels, which are different from track to track. The FTM maintains the assigned flight levels with the specific track.

c. Once the flight data are read using the flight plan file generated by the FPM and Track Designation Routine, the aircraft enters a delay block until it is given the initial clearance. This ensures the aircraft completes the clearance procedures before its entry time into the system.

d. The flight then enters its initial clearance. The initial clearance requires the utilization of the conflict detection and conflict resolution algorithms. The conflict detection algorithm determines whether any previously declared aircraft has a conflict with this aircraft flight plan. After returning from the conflict detection algorithm, the model determines whether a conflict was detected. If none were found, the aircraft is scheduled for entry into the system. If a conflict is detected, the flight is sent to the conflict resolution

algorithm, where it is given an alternative flight plan and returned to the conflict detection algorithm once again. The iterative process ends with the scheduling of all aircraft in the flight plan file.

e. When the clock time reaches the NAT entry time of a flight, the Fuel Burn Module, MET Module, and aircraft specific parameters are utilized. The great circle distance from origin to NAT entry point is determined. The weather for this route is supplied by the MET Module and is used to estimate the ground speed. The aircraft-specific parameters identify the normal ascent and climb rates for the flight's aircraft type. The Fuel Burn Module utilizes the estimated ground speeds, ascent and climb rates, and take-off weight to calculate the fuel consumed from origin to NAT entry. The FTM stores the fuel consumed from origin to NAT entry point for each flight.

f. As an aircraft enters its oceanic entry point, the current node of the aircraft is incremented to one, referring to the oceanic entry point. The cruise speed provided by the FPM in the flight plan along with the MET Module are used to estimate the flight time of arrival at its second waypoint. The time of travel between waypoints is estimated using a great circle distance between points. The aircraft is then scheduled to arrive at its second waypoint, using the calculated travel time. However, step climbs may be requested and granted for the arrival to the next waypoint and thus the actual flight plan might be changed. This request may be initiated at a waypoint or during the travel to the next waypoint. A step-climb procedure only grants step climbs at waypoints, so a request may be for any waypoint beyond the previous waypoint as long as the request is initiated 15 minutes or more before the estimated time of arrival to the next waypoint.

g. Once the aircraft arrives at the next waypoint, the model determines if the flight plan is complete. The flight plan is complete if the next waypoint is the oceanic exit point. If complete, the aircraft departs from the NAT airspace, total fuel consumed is estimated, statistics are summarized, and the aircraft entity is terminated from the model. If the aircraft has not completed its flight plan, the model determines if the estimated time of arrival at the next waypoint is no more than 1/10 of a minute different than the actual time of arrival. If the time difference is greater, the conflict detection and conflict resolution algorithms are called to reclear the aircraft flight plan.

h. The aircraft now has reached its next waypoint in the flight plan, so the current node of the aircraft is incremented by one. The time of arrival is again calculated for the aircraft for rescheduling to the following waypoint in its flight plan. Each time an aircraft reaches a new waypoint, the Fuel Burn Model is called to estimate the fuel consumed. The MET Module supplies the current meteorological conditions based on the clock time and the location coordinates of the flight. This process is continued until all the waypoint crossings have been completed.

Step-climb is an important feature in the FTM. Step-climb requests are made only if the aircraft is operating at an altitude lower than the altitude specified by FPM in its original flight plan. A flight can initiate a step-climb request during the position report transmission. Each flight is required to make a position report to ATC at every waypoint. Combining the step-climb request with the position report rather than initiating a separate step-climb transmission minimizes the number of communications to the ATC. To determine whether a request will be made, a random number between zero and one is generated. A small percentage, 4%, of all possible requests is

made; this is done to reflect what happens in the real system. The percentage is set to reflect the current High Frequency (HF) communication infrastructure across most of the NAT airspace. The historical data are also utilized in establishing the step-climb request percentage. The step-climb percentage in the Free Flight simulations is set to 100%, the percentage in all other separation simulations is set to 4%. Step-climb request must be made at least 15 minutes before the flight reaches its next waypoint and can be made only once before each waypoint crossing. The step-climb is granted only if the climb will result in a cleared path (e.g., free of conflicts) as determined by the conflict detection algorithm. If granted, the step-climb must be made before the flight initiates the next position report.

4.4.1 Reclearance Procedures

The tasks of the ATCS include conflict detection and conflict resolution. These two important tasks are part of the FTM. The conflict detection algorithm determines if a potential conflict will take place given information on two or more aircraft flight plans. Conflict resolution determines an alternate flight path if a conflict exists.

The conflict detection algorithm uses the ATC rules to check for separation violations. Before any flight enters the NAT airspace during the simulation, its entire flight plan is examined. Although the flight plans from the FPM contain step-climbs, the conflict detection algorithm ignores these step-climbs during the initial clearance. Flights are cleared at the entry altitude for the entire oceanic crossing. The flight may request a step-climb at a later time during cruise. If no conflicts are found, the flight enters the scheduling queue waiting for the simulation clock to reach its NAT entry time. If a conflict with another flight is expected to occur, the conflict resolution algorithm is called.

The conflict resolution algorithm utilizes a rerouting decision tree. Each time the algorithm is called, a change to the flight plan is recommended. The Canada Transport's NATTAM rerouting decision trees were modified and utilized to develop the reclearance logic for the FTM. The decision trees vary according to the separations specified in the simulation. As the separation standards are decreased, the routing algorithm has more options in its reclearance procedures.

During the simulation, the specific rerouting decision tree depends on the direction of the flight being rerouted. Therefore, there is a separate rerouting decision tree for eastbound and westbound flights. An example of the westbound rerouting decision tree for the Baseline, RVSM, and RVLSM scenarios is shown in Figure 22. The remaining conflict resolution rerouting decision trees used in the simulations are shown in Appendix J.

If the conflict detected is a violation in longitudinal separation, the conflict resolution algorithm may use the Mach Number Technique. This technique adjusts the speed of the aircraft affecting the longitudinal separation.

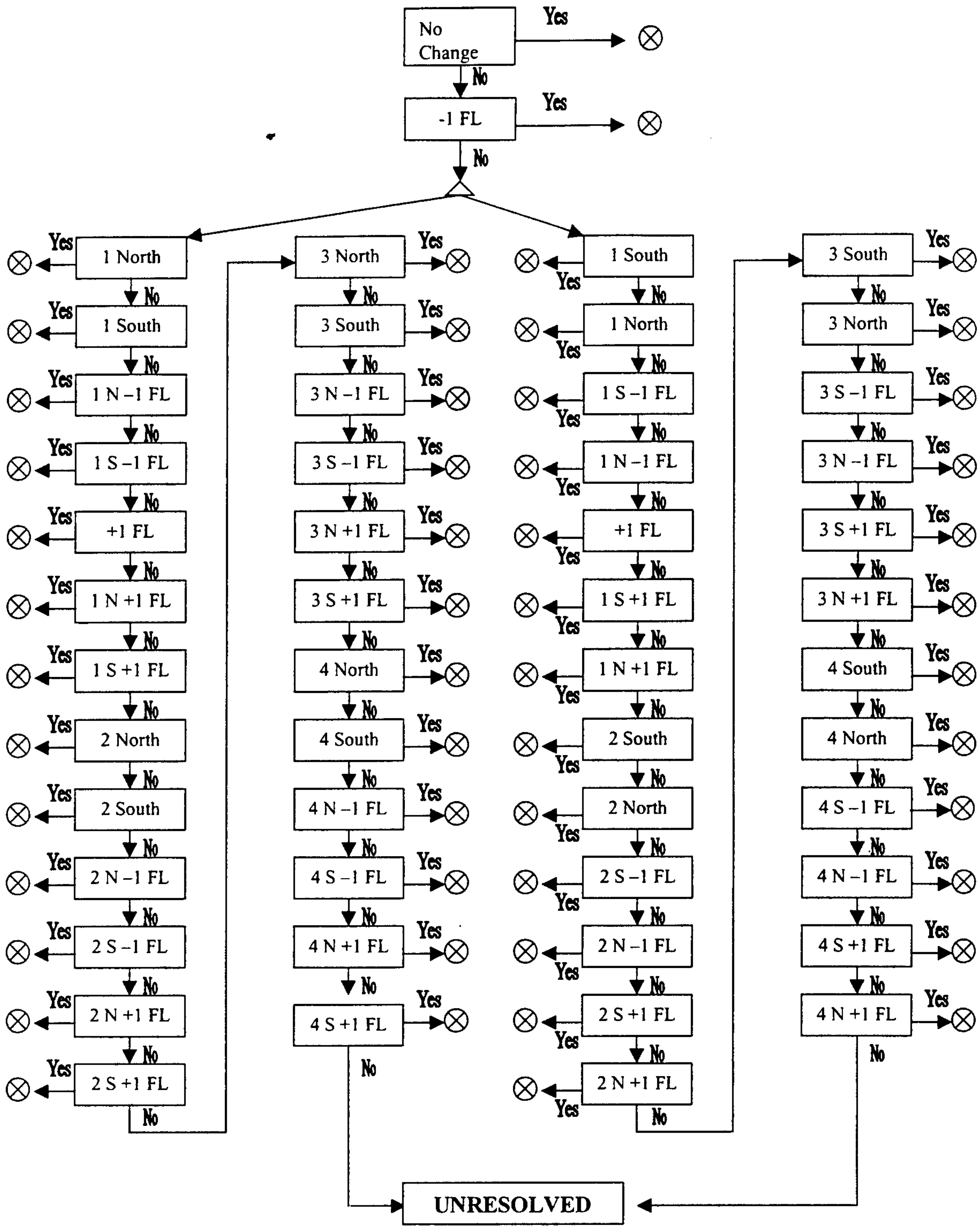


Figure 22. Westbound rerouting decision tree (Baseline, RVSM, and RVLSM).

If a conflict is detected and a resolution resulting in a cleared flight path cannot be found, the FTM will declare this conflict as unresolved. This means that the end of the rerouting decision tree has been reached, and none of the recommended changes to the flight plan have resulted in a cleared path for the aircraft. The conflict resolution algorithm then clears the aircraft with the original flight plan at a flight level lower than NAT MNPS. The first flight level attempted is 28,000 ft. If a cleared path is not found at 28,000 ft, then 27,000 ft is attempted, and so on. The number of unresolved flights is monitored in the FTM. Normally, there will be zero flights unresolved, but, occasionally, there are one or two flights unresolved during a simulation day.

4.5 Meteorological Module

The Bracknell Meteorological Office in the United Kingdom provides the weather data for this research. We used 6-hour forecast and actual weather data in the model. Except in the Free Flight scenario, forecasted weather is used in the FPM and the actual weather is used in the FTM. In the Free Flight scenario, perfect weather information is assumed to be available. Therefore, in the Free Flight scenario, both the FPM and FTM utilize the actual weather data.

The MET module provides wind information for five flight levels: 24,000 feet, 30,000 feet, 34,000 feet, 39,000 feet, and 45,000 feet. The longitudinal spacing of the data is 1.25 degrees, and the latitude spacing is 0.833 degrees. The wind components for points between the supplied grid structure are interpolated. Two wind components are supplied for each grid point, a westerly and southerly wind component. The westerly and southerly wind components are converted to wind magnitude and direction before being used in the model. The wind magnitude is computed using the Pythagorean theorem as shown in Figure 23.

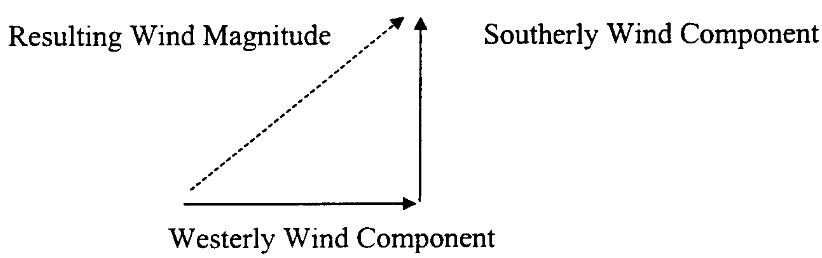


Figure 23. Wind vectors and resultant.

The wind direction is identified first. The correct quadrant for the resulting wind vector is determined and the wind direction is identified using an arc tangent function. Linear interpolation is performed when winds and temperature are requested for a flight level that does not match one of the five flight levels provided by Bracknell. Lateral and longitudinal interpolation is not performed in the model; the closest latitude and longitude in the grid provided is used in the weather calculations. Temperatures are not provided in the Bracknell data, therefore the standard temperature model is utilized.

The winds and temperatures are provided to other modules in the FPM and the FTM. In the FPM, weather data are used to determine the optimal flight path that minimizes fuel consumption for each aircraft. The weather data indicate the presence of the significant winds to the Fuel

Burn Module. The resulting optimal flight paths are based on the weather data for the simulated day. In the FTM, the weather data are used in determining the travel time and fuel consumed throughout the NAT crossing.

4.6 The Fuel Burn Module

The fuel consumption is calculated for each flight during the simulation based on fuel burn tables provided by Lufthansa Airline. The Lufthansa fuel burn tables provide fuel consumption rates for the specified aircraft type, speed, altitude, and weight of the aircraft.

Fuel tables are provided for the 11 aircraft types in the TFG aircraft distribution. Table 17 lists the aircraft types for which the fuel tables are available. These eleven aircraft types do not represent all of the aircraft types used in the NAT. Therefore, several equivalencies are made in order to simulate all the flights contained in the historical data for the NAT. The equivalencies made for fuel consumption calculations are presented in Table 18. The model number corresponds to the label shown in Table 17.

The fuel consumption of an aircraft is a continuous function of its weight. The change in aircraft weight in a small time interval is negligible. We separate the distance between waypoints for fuel consumption calculation into 500-nm intervals at the cruising altitude. This separation provides good approximation for fuel consumption without the burden of extensive computations [11]. The fuel consumption calculation requires that the weight of the aircraft be known at the beginning of each 500-nm interval. In order to determine such a weight, the weight of the aircraft at the start of the flight (e.g., the take-off weight) is required for the Fuel Burn Module.

The Flight Events Module provides the take-off weight and departure time. The fuel consumption before the entry to the NAT airspace is calculated in phases: the takeoff phase calculates the fuel burned to reach 1,500 feet assuming constant acceleration. The aircraft continues to accelerate until it reaches its normal indicated airspeed (IAS). The normal IAS is determined from the aircraft specific parameters provided by Lufthansa. The aircraft continues its ascent at the normal IAS throughout the first ascent phase. During the first ascent phase, the aircraft travels from 1,500 feet to 10,000 feet. By maintaining the normal IAS, the aircraft is constantly accelerating relative to its true air speed (TAS). When the aircraft reaches 10,000 feet, a new IAS is reached and it enters the final phase of ascent, from 10,000 feet to NAT entry altitude. Constant acceleration is assumed until the aircraft reaches its cruising or MACH speed. The weight at the end of this segment is used as the weight of the aircraft at the entry into the NAT.

Once at cruising altitude and constant speed, the fuel consumed is calculated at intervals of 500-nm, as discussed previously. At the end of each interval, the new weight of the aircraft is computed (aircraft weight (lbs) at the beginning of the interval minus fuel consumed during the 500-nm interval (lbs)). This computation continues until the aircraft completes the NAT crossing.

Table 17. Aircraft for Which Fuel Tables are Available

Label	Aircraft Type
1	B767-200
2	B747-200
3	DC10-30
4	L1011
5	EA31
6	B747-400 (B74F)
7	MD11
8	B757-200
9	EA34
10	NICE Jet
11	B777

Table 18. Equivalence of Aircraft Types

Model Number	Aircraft Type	Model Number	Aircraft Type	Model Number	Aircraft Type
1	B767-200	8	MD80	10	E6A
2	B707	8	P3	10	G2B
2	B74	3	C141	10	G2
2	B74S	3	DC8	10	G3
2	B747-200	3	DC8F	10	G4
2	C135	3	DC8S	10	HS25
2	C137	3	DC10-30	10	L382
2	C5	3	KC10	10	L392
2	C5A	4	L1011	10	LR35
2	E3	10	AJ25	10	LR36
2	E4	10	BE20	10	LR60
2	IL62	10	BE30	10	N265
2	K135	10	BE33	10	SD36
2	KC35	10	BE90	10	SH5
2	KE35	10	C20A	10	SW3
2	KR35	10	C21	5	EA30
2	VC10	10	C414	5	EA31
8	B727	10	C550	5	EA32
8	B72S	10	CL60	5	EA33
8	B737	10	CL61	9	C17
8	B73F	10	D228	9	EA34
8	B757-200	10	D328	6	B74F
8	BA11	10	DA50	1	B767-300
8	DC9	10	DA90	7	MD11
8	C130	10	DHC8	11	B777

Once the aircraft reaches its oceanic exit point, the Fuel Burn Module estimates the descent fuel by computing the fuel from the NAT exit point to the destination airport. The flight will cruise until it reaches a descent point, which is estimated by the FTM. During the first descent phase, the aircraft travels from cruise altitude to 10,000 feet maintaining the normal descent rate defined in the aircraft specific parameters. When the aircraft reaches 10,000 feet, a new IAS is reached,

and the aircraft continues descending from 10,000 feet to 1,500 feet. The flight then continues the descent from 1,500 feet to the destination airport. The final fuel burn for the flight is calculated and recorded. The fuel calculations performed throughout the aircraft trajectory are summarized in Figure 24.

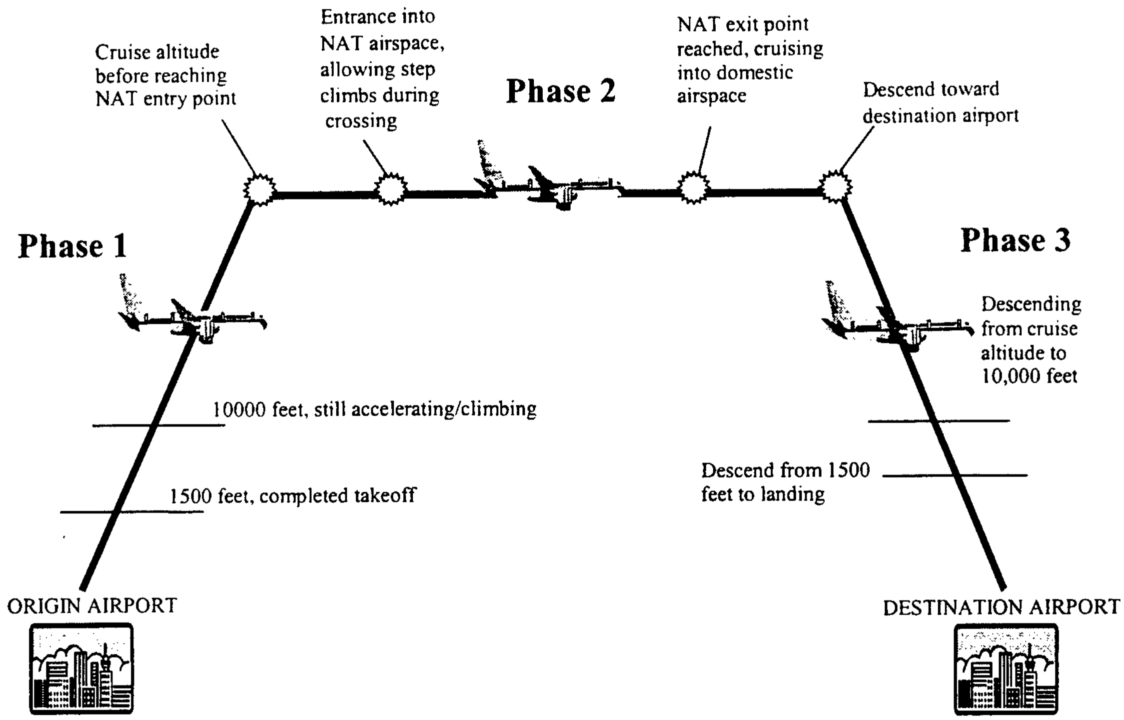


Figure 24. Aircraft trajectory.

Due to the simplified ascent phase from origin airport to cruise altitude and the simplified descent phase from NAT exit point to destination airport, a correction for the fuel computation is made. An adjustment is made to the take-off weight before the ascent phase begins. Another adjustment is made to the total fuel burn after the descent phase completes. These adjustments are based on real data and were supplied by the NICE-ICE task group.

The FTM is written using a fast-time computer simulation language, GPSS/H by Wolverine Software. The conflict detection and conflict resolution algorithms are written in the GPSS/H language as well. The Fuel Burn Model and the MET Module are written in the FORTRAN language.

4.7 Model Assumptions

This section summarizes the modeling assumptions made in this study. The assumptions common to all three NICE studies are presented first. The remaining assumptions are unique to the NICE-USA simulation methodology.

4.7.1 NICE Simulation Assumptions

A sample of 24 study days is used to obtain the fuel savings results. The study days are the 4th and 15th of each month in 1996. This extensive set of study days is necessary to accurately estimate the expected fuel burn consequences of the separation scenarios. Variations in the seasonal traffic volume and traffic patterns (due to differences in weather conditions from day to day) necessitate this large sample.

4.7.1.1 NICE Aircraft Types

The 1996 TFG distribution of the top 11 aircraft types represented over 92% of the aircraft types used in the NAT in the year 1996 (see Table 2). This study categorized every aircraft in the NAT airspace as one of these 11 aircraft types. Fuel characteristics of these 11 aircraft types are obtained and used in the simulation model.

4.7.1.2 NICE Fleet Changes

The NAT fleet change forecasts are incorporated in the Flight Events for future years' traffic samples. This fleet forecast has the effect of replacing 'older' aircraft types like the DC10 and B747-200 with 'newer' types like the B777 and the Airbus 340. This is described in Section 3.2; the forecast details are given in Table 3.

4.7.1.3 Organized Track System

The actual OTS from the 24 study days in 1996 is used in the simulation of the Baseline system. NICE-ICE generates two additional sets of OTS tracks for use with the RVSM and RVHSM scenarios. The NICE-ICE method for OTS generation involves a fast time simulation display of the real traffic from the 24 study days in 1996. The OTS forecast for the separation scenarios is then generated with expert input from Gander, UK, and Iceland, using the NICE-ICE simulator and the TFG forecasts. The OTS for the different scenarios is as follows:

- Baseline System (the same as the actual 1996 OTS)
- RVSM (revised by eliminating outer tracks)
- RVLSM (same as RVSM)
- RVHSM (revised by compacting the tracks)
- Free Flight (no OTS)

The OTS is used in the simulation of all scenarios for the 24 study days and in all 4 years except in the Free Flight scenario where no OTS was applied.

The OTS and the weather patterns for the low traffic day March 4th, the medium traffic day October 15th, and the high traffic day August 4th are shown in Figures 25 through 30[5].

[5] Figures 25 through 30 were generated by the NICE-UK Task Group.

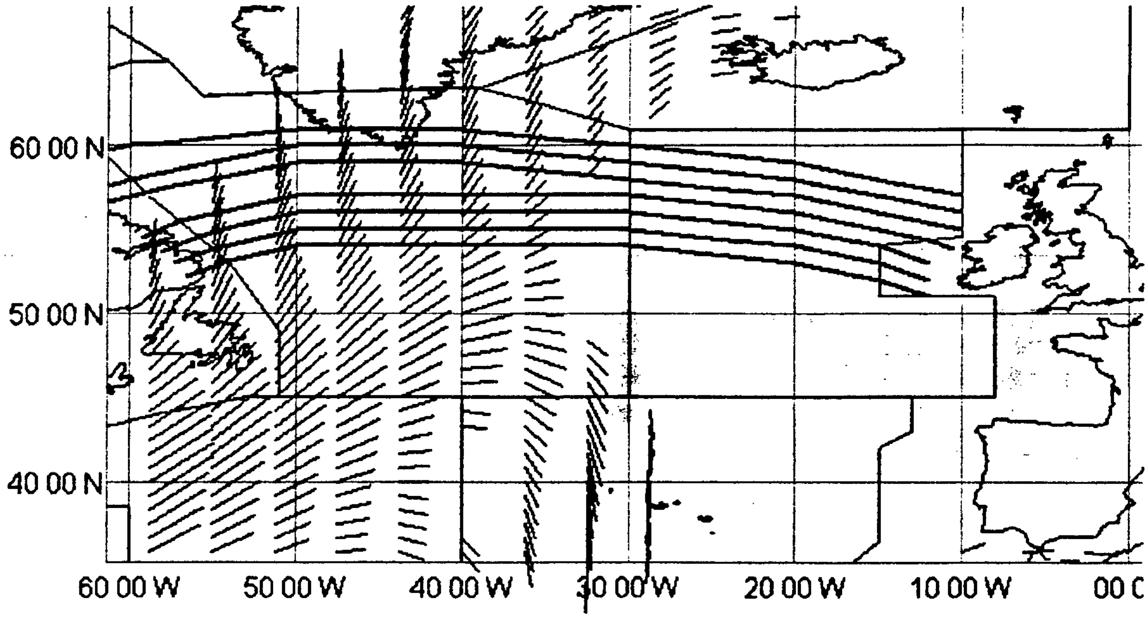


Figure 25. Westbound OTS for March 4.

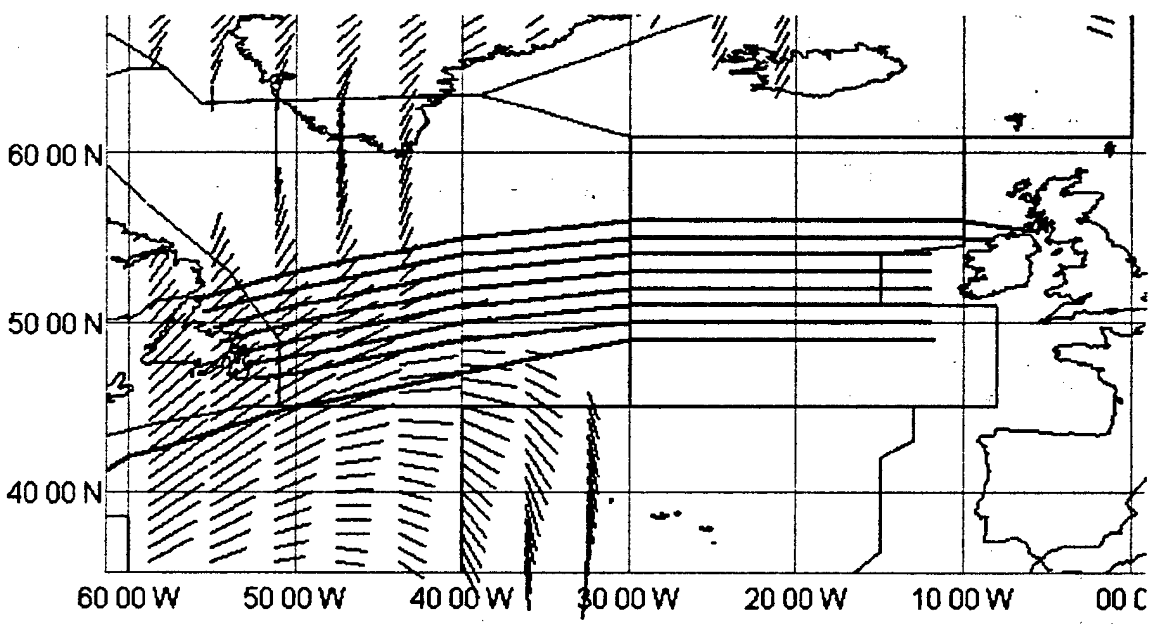


Figure 26. Eastbound OTS for March 4.

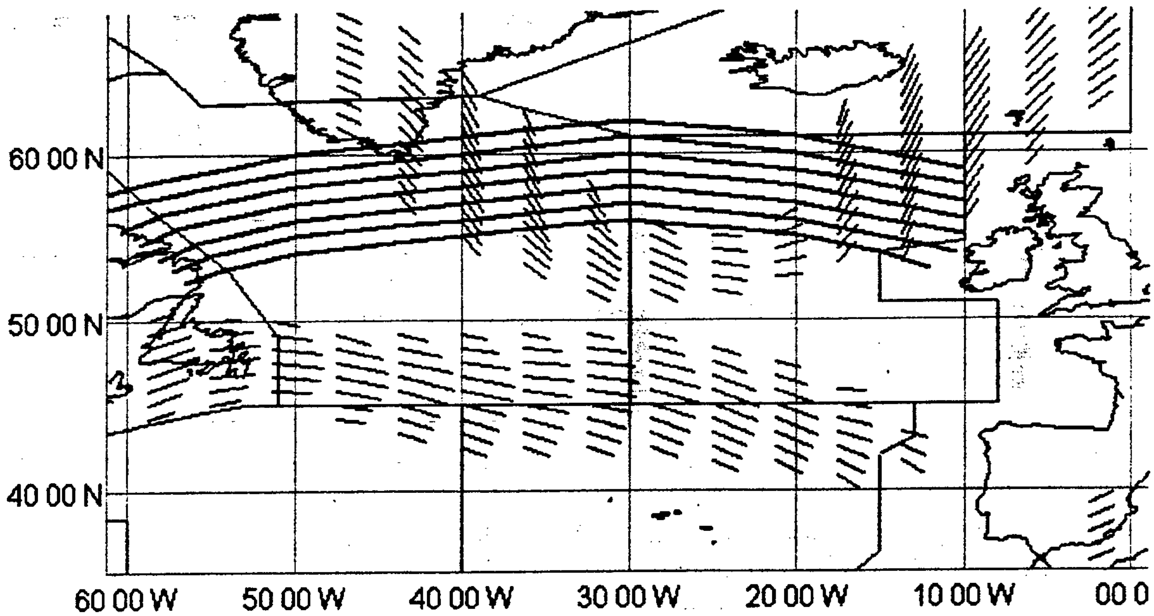


Figure 27. Westbound OTS for August 4.

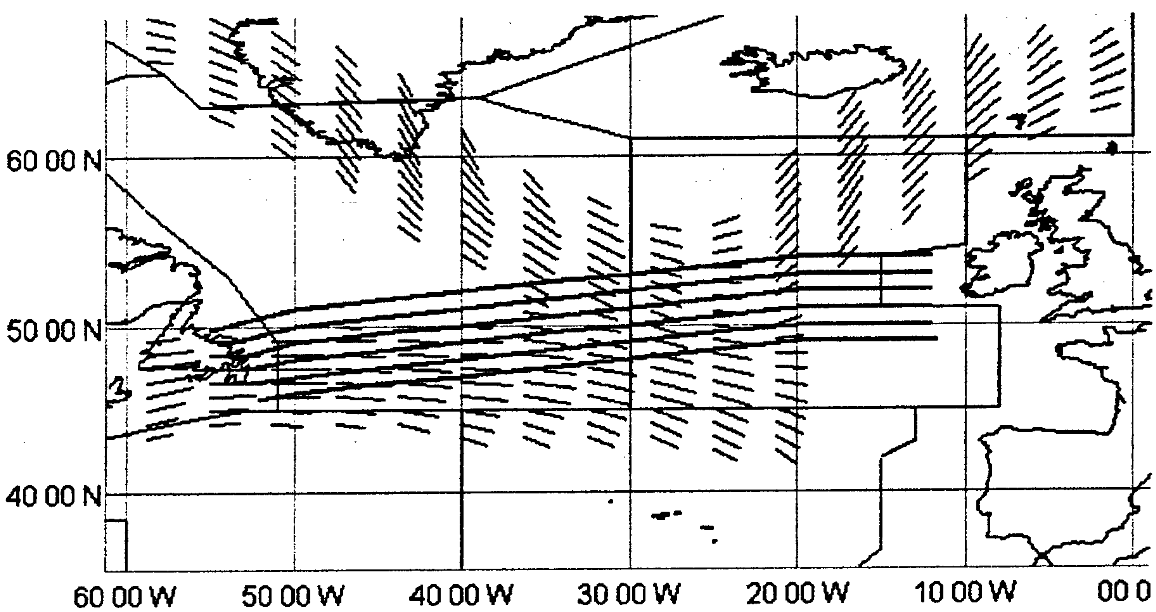


Figure 28. Eastbound OTS for August 4.

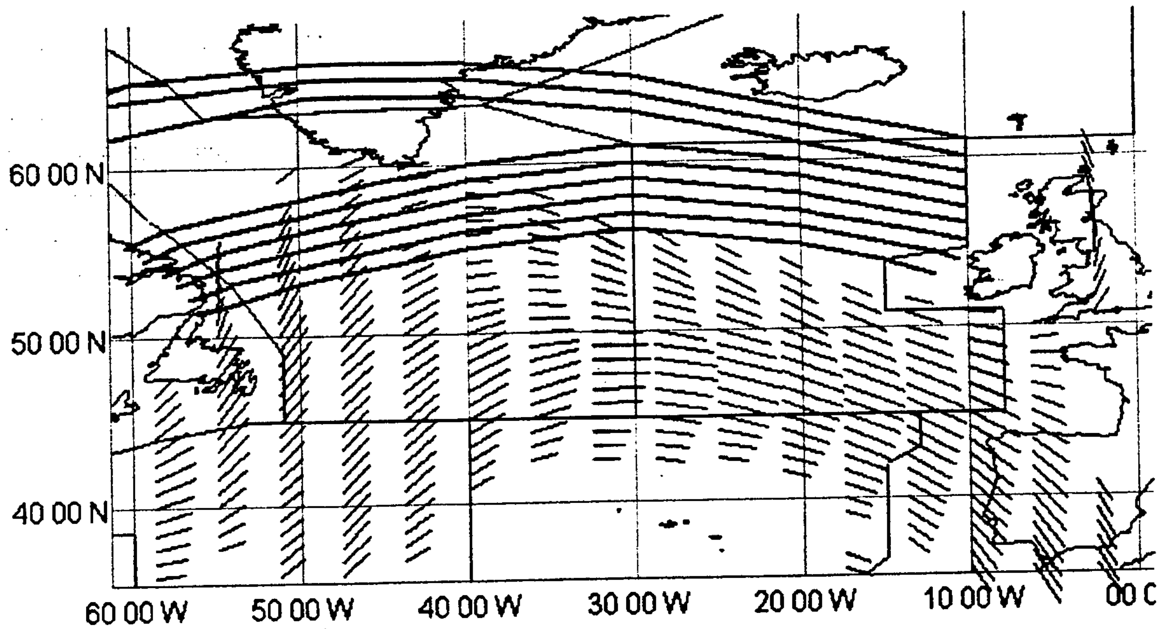


Figure 29. Westbound OTS for October 15.

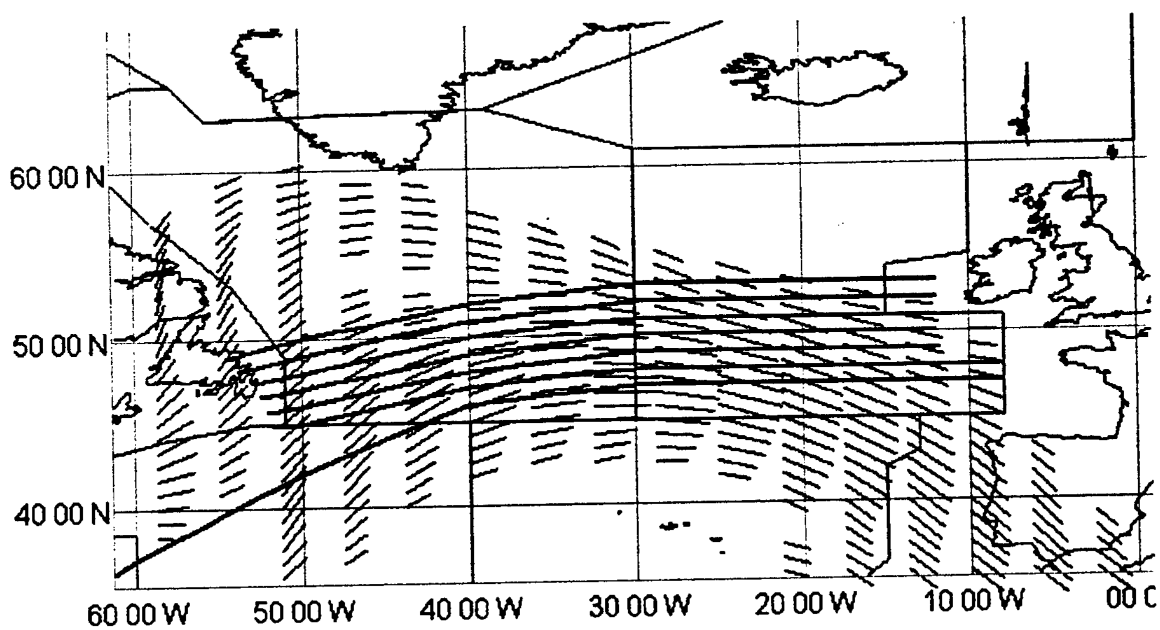


Figure 30. Eastbound OTS for October 15.

4.7.1.4 Meteorological Data

The wind conditions from each of the 24 study days in 1996 are applied. All scenario simulations, except Free Flight, use the forecast wind data in the FPM and the actual wind data in the FTM. In the Free Flight scenario, the actual wind data is used in both the FPM and FTM to simulate the availability of perfect MET data. The MET Module is discussed in Section 4.5 and the use of the MET data is discussed in Section 3.4.

4.7.1.5 Simulated Flight Path

This study examines the oceanic portion of flight only; domestic routings are not simulated in the model. Each aircraft operates on an optimal fuel path from the origin airport to its NAT entry point and from the NAT exit point to the destination airport. The reclearance procedures are applied during the NAT portion of flight only.

4.7.1.6 Fuel Burn Calculations

The fuel burn for each civilian flight is calculated over the entire flight path in the NAT. Military flights are included in the study to simulate the congestion effects; the fuel for military flights is not reported. Fuel burn comparisons are made using the total fuel burn (NAT and domestic fuel burn) calculated for each flight. The NAT fuel burn is not used for comparisons due to the fluctuations in the distances flown within the NAT FIRs from scenario to scenario.

4.7.2 NICE-USA Simulation Assumptions

4.7.2.1 Traffic Samples

Simulations of the 24 study days with 1996 traffic volume are performed twice. The first set of 1996 simulations use the actual flights that occurred on each study day and the second set use the traffic samples generated by the Flight Event Module for 1996. The remaining years, 2000, 2005, and 2010, simulate the traffic generated by the Flight Event Module for the 24 study days.

4.7.2.2 Take-off Weights

The simulations using the traffic samples generated by the Flight Event Module assume the same take-off weight for each flight in all scenarios. A description of the statistical take-off weight generation is found in Section 3.3.5.

Three study days of actual flight data in 1996 (March 4, August 4, and October 15) use the scenario take-off weights generated by Lido. The remaining 21 study days of actual flight data in 1996 use the Baseline System take-off weight generated by Lido in all scenarios.

4.7.2.3 Step-Climbs

The FPM generates flight plans that contain step-climbs. During the traffic simulation (FTM), the probability of a step-climb request in each scenario is controlled in the model. Each time an aircraft approaches a waypoint in the NAT, the model checks its desired flight level listed in the flight plan and compares it to the current operating level. If the aircraft is operating at a lower

flight level than the level listed in the flight plan, a step-climb request may be possible. The probability of a step-climb request is kept at 4% for all scenarios (based on empirical observations). The step-climb request probability in the Free Flight scenario is set to 100%. Details on the step-climb procedures applied in this study are given in Section 4.4.

4.7.2.4 Communications Efficiency

The probability of a step-climb request in this study assumes that the level of communication support in the airspace remained unchanged in the Baseline, RVSM, RVLSM, and RVHSM separation scenarios. Portions of the fuel benefits may be attributed to the step-climb request percentages.

4.7.2.5 OTS and Random Flight Classification

The FPM generates an optimal fuel path for each flight. Before the traffic simulation (FTM), geographical comparisons between the optimal fuel path and the OTS are made for each flight. The flights meeting the OTS criteria, whose optimal fuel path is within one lateral degree of a specific track on the OTS, are assigned to the OTS. The remaining flights are kept as Random flights. Details on the OTS / Random flight classification are given in Section 4.3.1.

4.7.2.6 NICE-USA Reclearance Logic

The FPM generates an optimal fuel path from the origin airport, through the NAT airspace, to the destination airport for each flight. During the traffic simulation, each flight operates on the optimal fuel path from the origin airport to NAT entry. Before entry into the NAT airspace, the FTM applies the reclearance logic to provide a conflict-free path for each flight. Once the NAT portion of flight is complete, each flight operates on the optimal fuel path from the NAT exit to the destination airport. The reclearance logic applied is dependent on the separation scenario and the direction of the flight. Specific details on the NICE-USA reclearance procedure are given in Section 4.4.1 and Appendix J.

5. Cross Validation and Verification

The three groups involved in the modeling of the air traffic in the NAT airspace, NICE-USA, NICE-ICE, and NICE-UK performed extensive cross validation and verification of the three models. All three simulation models approach the problem using different methods. Although the methods are different, certain elements can be compared. In this section we show the cross validation results of the following:

a. FE Real (real flight events from 1996) with FE Stat (Statistically generated flight data)

b. Flight plan comparisons with NICE-ICE and Lido (Lido created the flight plans for NICE-ICE. Lido specializes in flight planning and optimization).
   1. Average Fuel Consumption
   2. A Sample of 36 Flights

c. Conflict detection and conflict resolution logic

d. Animation snapshots of the FTM

5.1 FE Real and FE Stat Validation

The average fuel consumption per flight in the FE Real with take-off weights generated by Lido is compared with the average fuel consumption per aircraft from the FE Stat with statistically generated take-off weights. The cross validation of FE Stat vs. FE Real is performed by comparing the flight planning results and the ATC simulation results from the two flight event sources.

The fuel consumption comparison from flight planning is shown in Table 19. Table 19 represents the average of 24 days with four scenarios for every day. The differences between the mean fuel consumption using the FE Stat and the mean fuel consumption using the FE Real are small. An added factor in this comparison is the statistically generated take-off weights in the FE Stat and the Lido take-off weights in the FE Real. The differences in the flight events and the take-off weights make it less probable for the average fuel consumption per aircraft to match in the comparison. However, the small difference between the average fuel per aircraft shows a good approximation of expected flight events is obtained from the FE Stat distributions.

Table 19. Average Fuel Consumption per Aircraft

1996	Baseline	RVSM	RVHSM	FF
FE Stat	116,689.47	116,680.45	116,563.56	116,541.44
FE Real	116,303.64	116,230.53	116,128.32	116,131.09
Percentage Difference	0.33%	0.39%	0.37%	0.35%

The average fuel benefit resulting from FE Real and FE Stat is compared for all scenarios in 1996. The difference in the average fuel benefit between FE Real and FE Stat in 1996 is shown in Table 20.

Table 20. 1996 Fuel Benefit Comparison: FE Stat vs. FE Real

	RVSM	RVLSM	RVHSM	FF
Average FE Real	0.56%	0.65%	0.79%	2.73%
Average FE Stat	0.53%	0.58%	0.72%	2.66%
Difference	0.03%	0.07%	0.07%	0.07%

The daily fuel benefit comparison is illustrated for the RVSM and Free Flight scenarios in Figures 31 and 32.

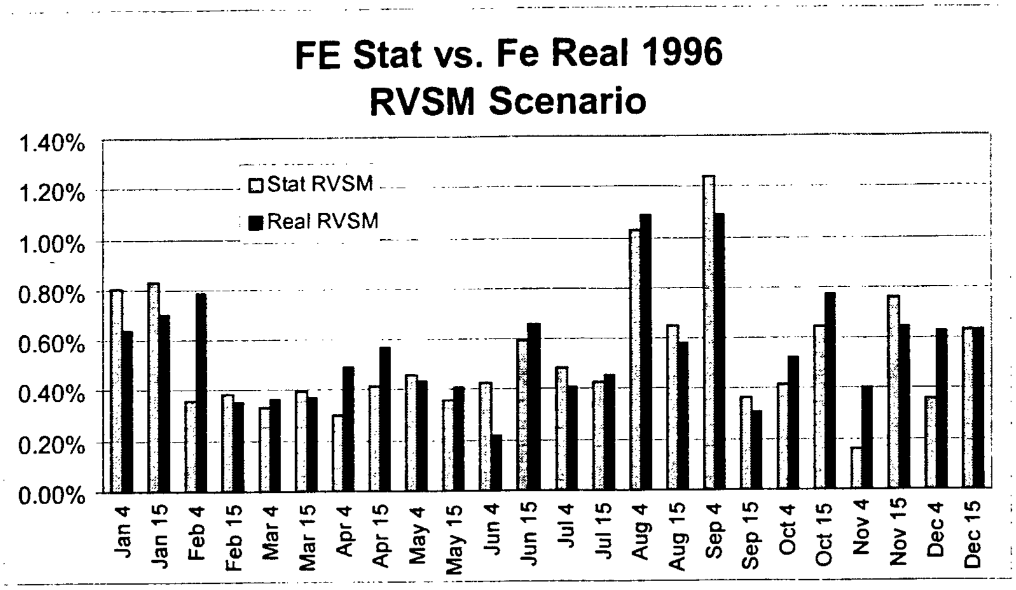


Figure 31. FE Stat vs. FE Real fuel benefit comparisons for the RVSM scenario.

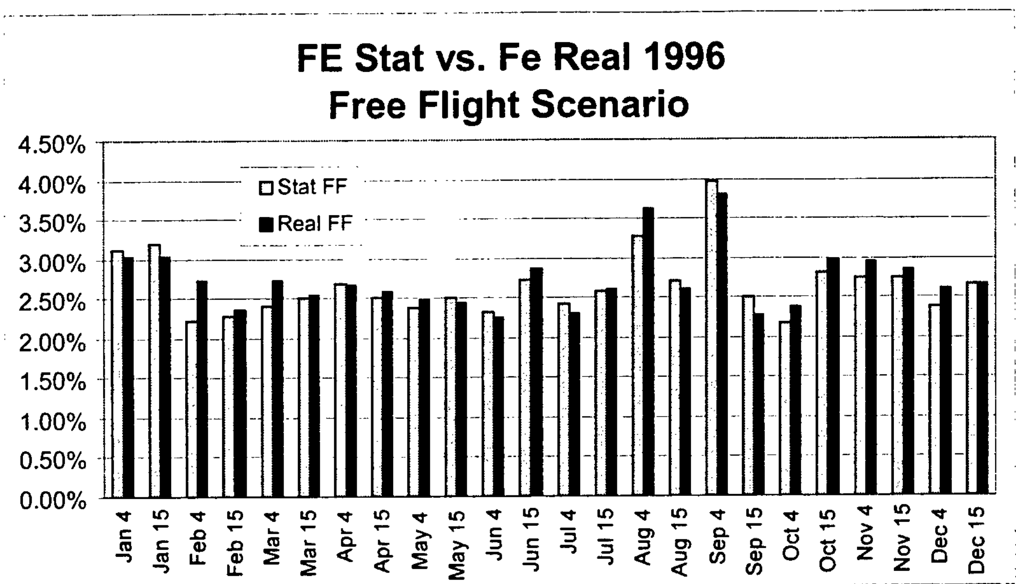


Figure 32. FE Stat vs. FE real fuel benefit comparisons for the Free Flight scenario.

The differences between the mean fuel benefits using the FE Stat and the mean fuel benefits using the FE Real are small. The factors affecting the fuel benefit differences are the different flight events and different take-off weights. Even with the additional factor of the take-off weight, the small difference between the fuel benefits shows a good approximation of expected flight events is being obtained from the FE Stat distributions.

5.2 Flight Plan Comparisons with NICE-ICE (Lido GmbH)

The cross validation results obtained from the NICE-USA flight plans are compared with those obtained from NICE-ICE and Lido models. This comparison is accomplished as described in the following sections.

5.2.1 Average Fuel Consumption

NICE-ICE and Lido use the FE Real for year 1996 with the given aircraft payload to obtain a corresponding take-off weight. The take-off weights are then used to obtain an MTT optimal flight plan for every flight. NICE-ICE and Lido supply their optimal flight plans with the corresponding take-off weights and flight information to NICE-USA for cross validation purposes.

These take-off weights from NICE-ICE and Lido are assigned to the corresponding flights in the FE Real for every 4th and 15th day of year 1996 in preparation for the NICE-USA FPM. NICE-USA use this FE Real containing the NICE-ICE take-off weights and obtained the corresponding optimal flight plans using the FPM. The average fuel consumption obtained from the FPM for every aircraft type is compared with the corresponding aircraft type in the Lido flight plans. The results for the total number of every type of aircraft during 1996 are reported in Table 21.

Table 21. Comparisons of Fuel Consumption for Every Aircraft Type for 1996

Aircraft Type	No. Of Aircrafts	NICE-USA Fuel (avg lbs)	Lido Fuel (avg lbs)	Difference (avg)
B767-300	5560	83,024.35	83,801.72	-0.93%
B747-200	3554	181,659.15	180,738.98	0.51%
DC-10	1712	137,566.78	136,014.10	1.14%
L1011	928	118,620.53	116,234.91	2.05%
EA31, A310	585	73,742.45	73,156.58	0.80%
B747-400	1018	178,354.31	178,170.61	0.10%
MD11	1077	117,914.70	116,256.62	1.43%
B757-200	1269	31,005.78	31,197.01	-0.61%
EA34	1129	104,536.85	105,395.59	-0.81%
NICE Jet	634	7,838.11	36,230.60	-78.37%
B777	296	99,063.08	99,777.43	-0.72%

The discrepancy in the NICE-Jet category is attributed to the difference in modeling the NICE-Jet in both the NICE-USA and NICE-ICE models. NICE-USA considers the NICE-Jet as a business jet equivalent to a B757 with regards to performance (speed), but its take-off weight was equivalent to a typical business jet (e.g., much lighter in take-off weight than a B757). NICE-ICE and Lido use the given payload and generated a take-off weight equivalent to a B757 for the NICE-Jet. These larger take-off weights are input into the FPM, which results in the inconsistent results shown in Table 21. The discrepancies are removed when the fuel consumption obtained by NICE-ICE is divided by five. It was agreed that the take-off weight of the B757 is about five times that of a business jet.

Table 21 is repeated for several days in year 1996 as illustrated in Figures 33 and 34. The average fuel per flight for both east and west directions is shown in Table 22.

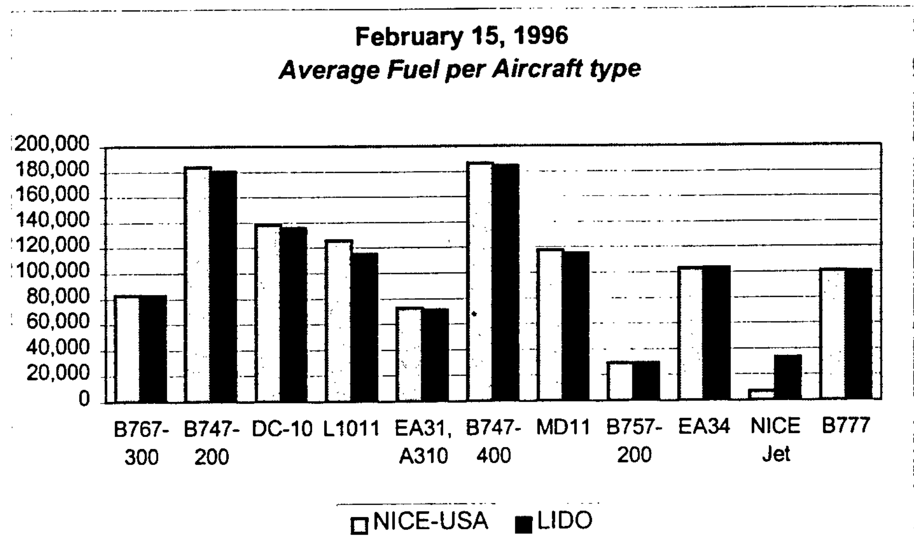


Figure 33. Average fuel-per-aircraft type for February 15, 1996.

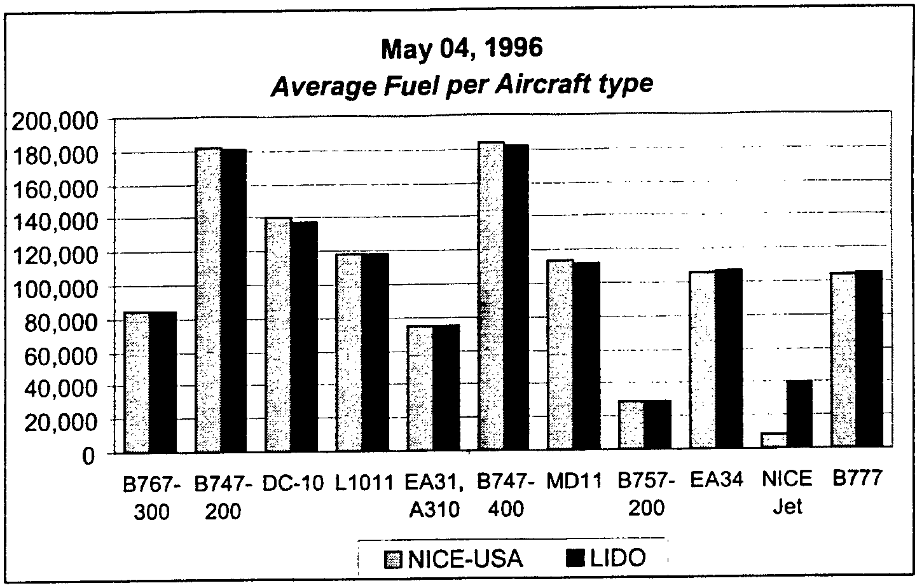


Figure 34. Average fuel-per-aircraft type for May 4, 1996.

Table 22. Fuel Consumption Per Flight Based on the Total Flights for 1996

Direction	No. Of Aircrafts	NICE-USA Fuel (avg lbs)	Lido Fuel (avg lbs)	Difference (avg)
East	8577	109439.1845	108661.4807	0.72%
West	8551	123091.5167	123320.5356	-0.19%

The average fuel consumption per flight for the 24 days of 1996 is obtained from the NICE-USA FPM and Lido flight planning algorithm as shown in Table 23. The difference ranges between 0.00 and 1.43%. This validates the flight planning procedures for both NICE-USA and NICE-ICE.

5.2.2 A Sample of 36 Flights

Thirty-six flights from October 15, 1996 are chosen for cross validation. These flights represented all types of aircraft and a range of origins and destinations. The flight plans obtained by NICE-USA and NICE-ICE (Lido flight plans) are compared for each flight in terms of fuel consumption in metric tons, flight levels in feet, and lateral difference in degrees. Because of the difference between NICE-USA and NICE-ICE in modeling NICE-Jet, it is eliminated from the percent difference comparisons as shown in Table 24.

The average percent difference in flight time (origin-destination) is about 3 min or 0.02% and in fuel consumption is about 0.07 tons (about 0.004%). This is an excellent indicator of closeness of the results.

Table 23. Average Fuel Consumption per Aircraft for the 4th and 15th Day of Each Month

Date	No. Of Aircrafts	NICE-USA Fuel (avg)	Lido Fuel (avg)	Difference (avg)
04-Jan-96	724	113,134.55	111,662.15	1.32%
15-Jan-96	667	118,828.67	117,843.15	0.84%
15-Feb-96	686	118,963.97	117,288.86	1.43%
04-Mar-96	684	118,244.08	117,225.26	0.87%
15-Apr-96	749	118,086.75	117,825.71	0.22%
04-May-96	838	117,045.91	116,621.53	0.36%
15-May-96	771	114,023.35	113,926.90	0.08%
04-Jun-96	834	111,660.38	111,908.78	-0.22%
15-Jun-96	905	115,839.25	115,971.12	-0.11%
04-Jul-96	922	116,247.28	116,076.96	0.15%
15-Jul-96	923	115,605.09	115,792.94	-0.16%
04-Aug-96	1026	116,898.94	116,792.12	0.09%
15-Aug-96	926	118,361.33	118,026.44	0.28%
04-Sep-96	898	116,348.41	116,599.76	-0.22%
15-Sep-96	934	117,519.66	117,668.67	-0.13%
04-Oct-96	845	117,779.82	117,941.87	-0.14%
15-Oct-96	807	113,056.84	113,202.95	-0.13%
04-Nov-96	747	113,409.57	113,405.73	0.00%
15-Nov-96	748	116,409.81	115,707.06	0.61%
04-Dec-96	692	116,206.41	115,773.09	0.37%
15-Dec-96	802	117,856.08	117,567.23	0.25%

Table 24. Comparison Between NICE-USA and NICE-ICE (Lido) Flight Plans

USA	Lido	AC	Fuel Burn comparison (tons)				Time comparison (mins)			
ID	Callsign	Type	USA	Lido	Diff	% Diff	USA	Lido	Diff	% Diff
49	AAL67	1	**36.03**	**35.40**	**0.63**	1.78%	**483.90**	**470**	**14**	2.96%
582	LTU476	1	**45.68**	**46.20**	**-0.52**	-1.13%	**597.12**	**609**	**-12**	-1.95%
55	AAL79	1	**47.26**	**46.70**	**0.56**	1.20%	**582.13**	**578**	**4**	0.71%
659	RCH0020	2	**68.18**	**68.00**	**0.18**	0.26%	**387.81**	**389**	**-1**	-0.31%
450	DLH8160	2	**79.12**	**78.50**	**0.62**	0.79%	**444.82**	**443**	**2**	0.41%
443	DLH463	2	**93.96**	**93.90**	**0.06**	0.06%	**475.77**	**478**	**-2**	-0.47%
634	NWA39	3	**51.21**	**51.50**	**-0.29**	-0.56%	**395.34**	**398**	**-3**	-0.67%
505	IBE6620	3	**60.51**	**59.80**	**0.71**	1.19%	**467.28**	**468**	**-1**	-0.15%
326	COA19	3	**55.64**	**55.90**	**-0.26**	-0.47%	**409.87**	**414**	**-4**	-1.00%
587	NWA37	3	**60.04**	**60.00**	**0.04**	0.06%	**435.94**	**440**	**-4**	-0.92%
632	MON197P	3	**67.64**	**68.10**	**-0.46**	-0.68%	**484.15**	**497**	**-13**	-2.59%
243	BAW225	3	**75.32**	**75.20**	**0.12**	0.16%	**573.16**	**577**	**-4**	-0.67%
745	TSC224	4	**43.85**	**43.60**	**0.25**	0.57%	**348.66**	**348**	**1**	0.19%
386	DAL38	4	**56.80**	**57.00**	**-0.20**	-0.36%	**442.14**	**446**	**-4**	-0.87%
375	DAL19	4	**64.41**	**65.30**	**-0.89**	-1.36%	**481.73**	**497**	**-15**	-3.07%
586	MON083	5	**27.09**	**27.20**	**-0.11**	-0.40%	**364.86**	**371**	**-6**	-1.65%
173	AUA516	5	**31.10**	**30.90**	**0.20**	0.66%	**414.17**	**419**	**-5**	-1.15%
170	AUA502	5	**34.23**	**34.00**	**0.23**	0.69%	**426.97**	**433**	**-6**	-1.39%
710	SIA25	6	**59.00**	**59.10**	**-0.10**	-0.17%	**372.31**	**375**	**-3**	-0.72%
254	BAW282	6	**89.12**	**89.10**	**0.02**	0.02%	**564.29**	**568**	**-4**	-0.65%
538	KLM602	6	**96.92**	**97.40**	**-0.48**	-0.49%	**582.59**	**588**	**-5**	-0.92%
4	AAL104	7	**36.83**	**35.90**	**0.93**	2.59%	**343.44**	**346**	**-3**	-0.74%
480	FDX3	7	**55.03**	**54.80**	**0.23**	0.43%	**537.12**	**536**	**1**	0.21%
43	AAL57	7	**57.53**	**57.60**	**-0.07**	-0.12%	**532.55**	**531**	**2**	0.29%
513	ICE213	8	**8.02**	**8.20**	**-0.18**	-2.21%	**154.36**	**162**	**-8**	-4.72%
158	AIH018	8	**16.44**	**16.50**	**-0.06**	-0.37%	**310.93**	**317**	**-6**	-1.92%
748	TSC929	8	**25.25**	**25.30**	**-0.05**	-0.19%	**472.51**	**471**	**2**	0.32%
423	DLH409	9	**36.30**	**36.90**	**-0.60**	-1.61%	**386.93**	**392**	**-5**	-1.29%
422	DLH408	9	**43.37**	**44.70**	**-1.33**	-2.97%	**440.51**	**448**	**-7**	-1.67%
503	IBE6400	9	**61.10**	**61.70**	**-0.60**	-0.97%	**558.11**	**565**	**-7**	-1.22%
782	UAL917	11	**46.22**	**46.60**	**-0.38**	-0.81%	**466.41**	**467**	**-1**	-0.13%
780	UAL915	11	**47.99**	**48.50**	**-0.51**	-1.06%	**450.00**	**452**	**-2**	-0.44%
794	UAL941	11	**52.20**	**52.30**	**-0.10**	-0.19%	**487.64**	**488**	**0**	-0.07%
Overall	-	-	**1,729.41**	**1,731.80**	**-0.07**	**0.004%**	**14,876**	**14,981**	**--3**	**-0.02%**

The deviations in the vertical and lateral directions for the sample of 36 flights are shown in Tables 25 and 26 respectively. Similarly, 97% of the flights' levels are within ±2000 ft and 96% are within ±2° lateral. Figures 35 and 36 show the results graphically.

Table 25. Flight Level Deviations for NICE-USA and NICE-ICE

	SUM	-3000 ft	-2000 ft	-1000 ft	0	1000 ft	2000 ft	3000 ft
TOTALS	208	1	35	1	136	0	32	3
%	100.00%	0%	17%	0%	65%	0%	15%	1%

Table 26. Deviations in the Lateral Directions between NICE-USA and NICE-ICE

	SUM	- +	-4°	-3°	-2°	-1°	0°	1°	2°	3°	4°
TOTALS	208	3	5	9	28	51	87	19	10	2	1
%	100.00%	1%	2%	4%	13%	25%	42%	9%	5%	1%	0%

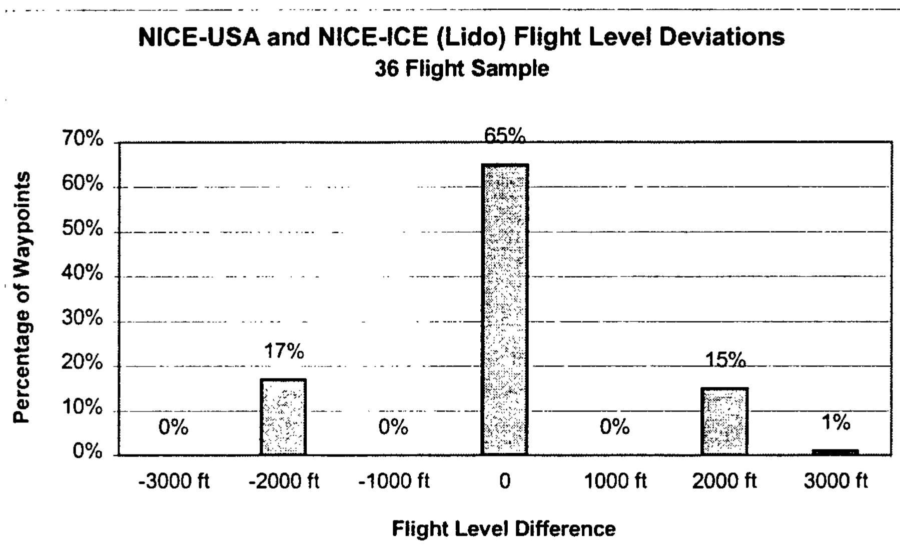


Figure 35. Flight level deviations for the 36 flight samples.

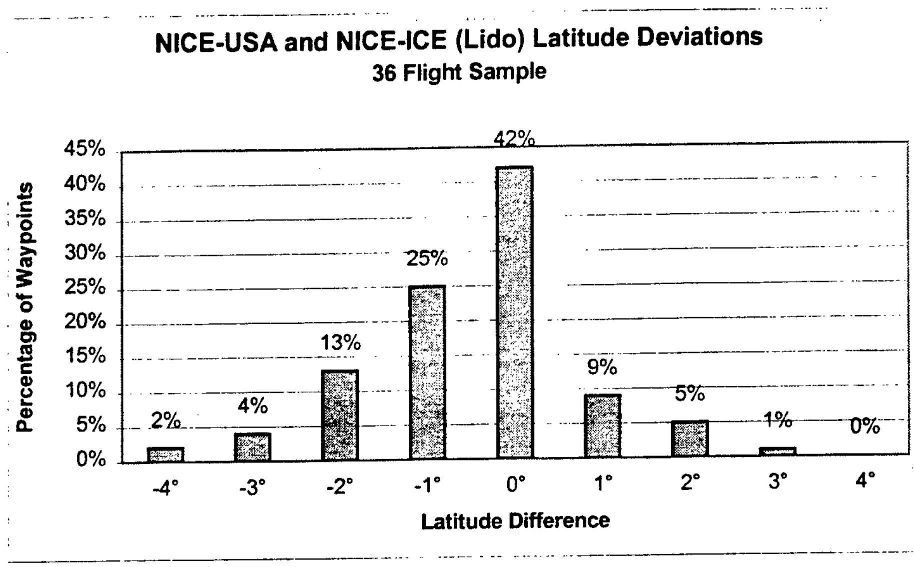


Figure 36. Deviations in the lateral direction for the 36 flight samples.

5.3 Conflict Detection and Conflict Resolution Logic

The FTM uses the optimal flight plans obtained from the FPM as the requested flight plans. The FTM clears all the flights using the ATCS clearance rules. During the FTM simulation, some flights are forced to deviate from their optimal plans due to conflicts with others. The reclearance procedures are described in detail in Section 4.4.1 of this report. The resulting fuel burn and flight path are stored for each flight. The total fuel consumption of all flights for a given day after clearance (FTM) are expected to be higher than the total fuel consumption of all flights obtained from the FPM.

The cross validation exercise conducted validates the NICE-USA conflict detection and reclearance logic with the NICE-ICE operational input. This cross validation method requires NICE-USA and NICE-ICE to run the traffic simulations with the same flight plans. NICE-ICE and Lido generated flight plans chosen for these exercises from FE Real for October 15, 1996.

We compare the total fuel burn and flight times obtained by NICE-ICE to the NICE-USA results. The comparisons are shown in Table 27 and 28.

Table 27. Re-clearance Results

	Number of Commercial Flights	Total Flight Time (hrs)	Total Fuel (kg)	Mean Fuel/Hour (kg/hr)
NICE-ICE	826	6206.213	41970613.29	6605.035
NICE-USA	826	6104.647	41957886.20	6700.628

Table 28. Re-clearance Comparison Results

	Total Flight Time (hrs)	Total Flight Time (%)	Total Fuel (kg)	Total Fuel (%)	Mean Fuel/Hour (%)
NICE-USA	-101.56	-1.6365 %	-12727.09	-0.0303 %	1.4473 %

The differences in the flight time and fuel are explained by the way each model simulates the traffic outside the NAT airspace. In the NICE-USA simulation, aircraft follow a great circle path from the origin airport to the NAT entry point. The aircraft follow this path at their cleared NAT entry altitude; no flight level changes are possible until the aircraft reaches the NAT MNPS airspace. After the NAT crossing, the aircraft leave the NAT airspace at their exit flight level and follow another great circle path from the NAT exit point to the destination airport.

The NICE-ICE model simulates the domestic routings outside the NAT airspace. Great circle distances are followed between the domestic points. Flight level changes specified in the domestic portion of the flight plan are allowed.

The flight plans received from NICE-ICE contain more location coordinates for each aircraft than the NICE-USA model required. The NICE-USA model requires an origin and destination airport, the NAT entry and exit points, and the waypoint crossings at 60W, 50W, 40W, 30W, 20W, and 15W. The additional points in the NICE-ICE flight plans are not included as input to the NICE-USA FTM. They affect the flight time and fuel burn for each aircraft causing NICE-ICE to show slightly higher fuel and time results than the NICE-USA. The comparisons between the models show they are in close agreement.

5.4 Animation Snapshots of the FTM

One of the most important validation steps in simulation modeling is viewing the animation. The animation is useful in verifying that the simulation model behaves correctly. Figures 37 through 40 show examples of the animation. The snapshots are taken from the October 15, 1996 Baseline System simulation.

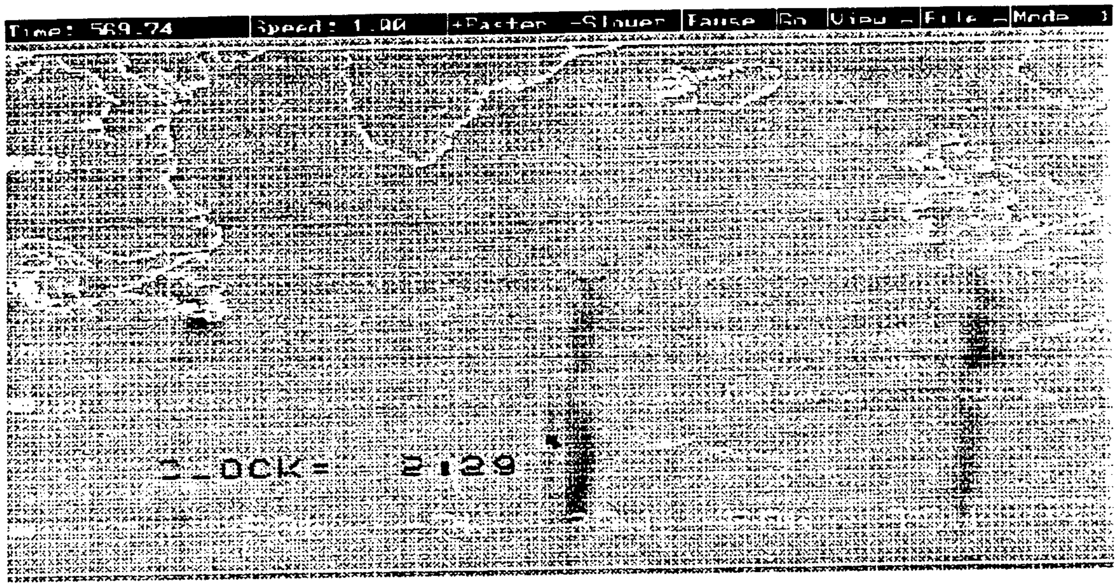


Figure 37. Snapshot of peak eastbound traffic flow.

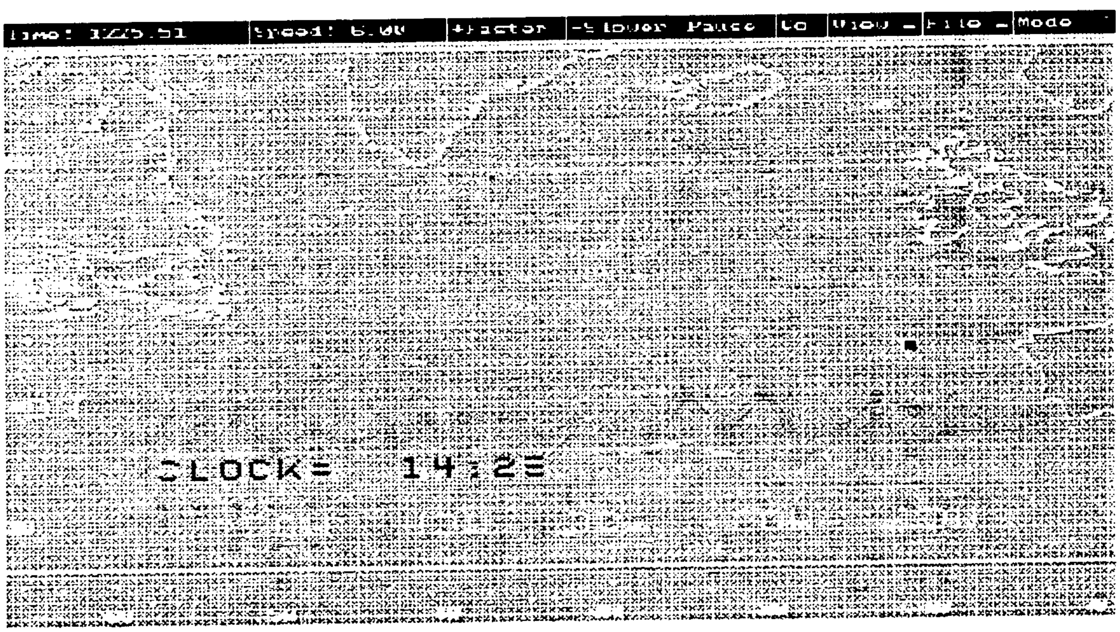


Figure 38. Snapshot of peak westbound traffic flow.

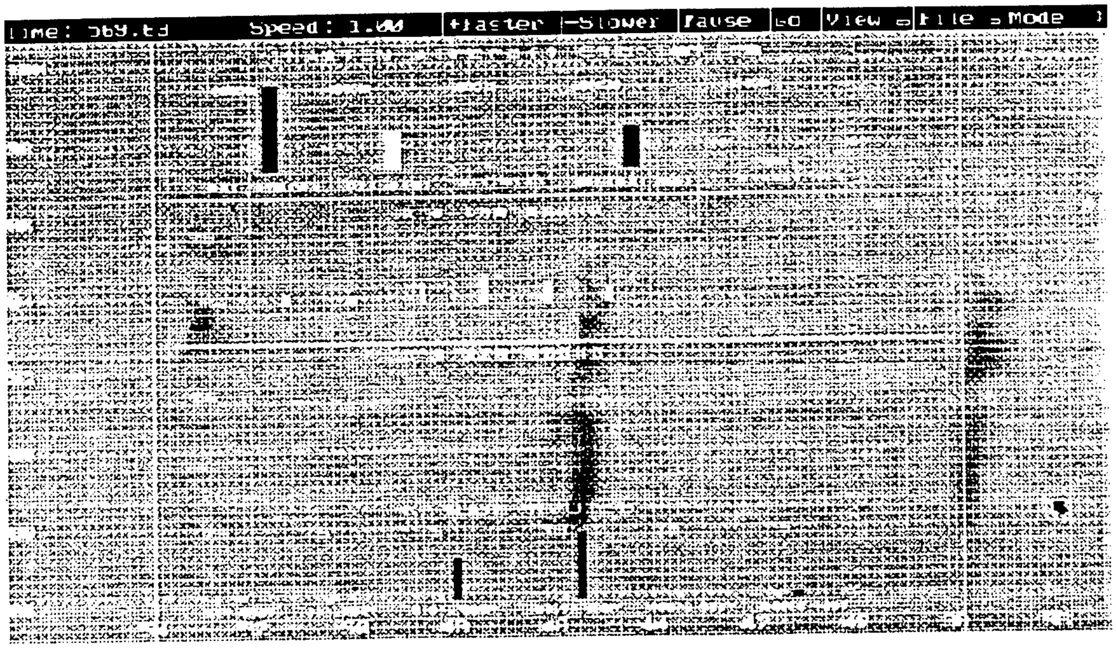


Figure 39. Snapshot of traffic monitors.

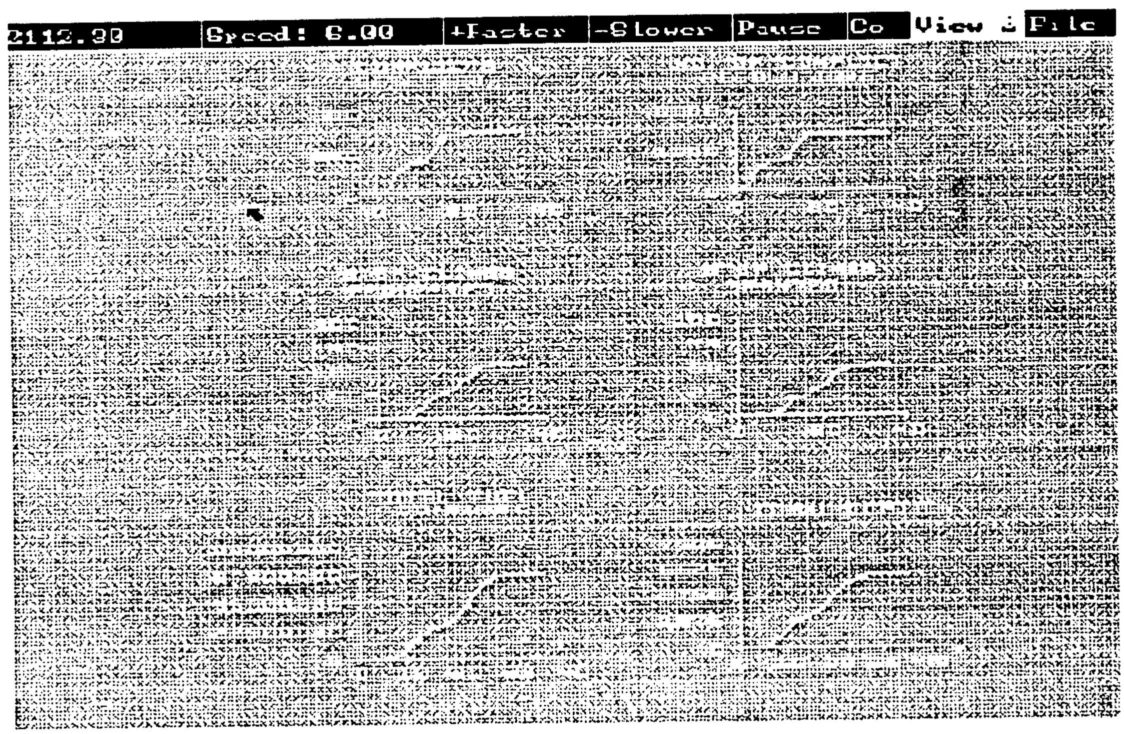


Figure 40. Snapshot of performance measure monitors (taken at the end of the simulation).

6. Results

In this section, we present the results for all the simulation scenarios. All scenarios were compared with the Baseline System (1996 system) where the separation distances of 2000 ft vertical, 60 nm lateral and 10 minute longitudinal are maintained. The results presented include

a. Fuel savings,
b. Communication volume,
c. Step climbs requested and granted, and
d. Conflicts detected and resolved.

We summarize two cases:

Case I – 24 days of simulation for each of the years 1996, 2000, 2005 and 2010 using FE Stat and statistically generated take-off weights

Case II - 24 days of simulation in 1996 using FE Real and baseline take-off weights generated by Lido for each scenario. Three of the 24 days, each representing a low, medium, and high traffic volume day, used take-off weights generated for each scenario by Lido instead of using the baseline take-off weights.

All results were obtained from the output of the simulation. Sample output of the FTM, the Fuel Burn module, and the FPM are shown in Appendix M, N, and O respectively.

6.1 Fuel Savings

Fuel savings for the scenarios were calculated as (Baseline fuel - Scenario fuel) / Baseline fuel. The model calculated the fuel expended (lbs) for a scenario of a given day by adding all the fuel consumed by all flights excluding military flights. It is important to note that the fuel calculated for each aircraft was the actual fuel used after the aircraft was cleared according to the ATC rules.

6.1.1 Case I Fuel Savings

The fuel savings for Case I are shown in Figures 41 through 44. In all years, the Free Flight scenario resulted in the greatest fuel savings.

The Free Flight scenario, as it is presented in this report, cannot be implemented. It represents an unrealistic system in which each flight obtains its optimal path regardless of other aircraft in the system. It also assumes that perfect weather information is available during flight planning.

Table 29 and Figure 45 present the summary of results for all years. As shown, in 1996, the RVSM scenario resulted in an average saving of 0.53% from the baseline, whereas RVSLM, RVHSM, and Free Flight scenarios resulted in an average savings of 0.58%, 0.71%, and 2.66%, respectively. The results for year 2000 showed RVSM with an average fuel saving of 0.57% from the baseline scenario, and RVLSM, RVHSM, and Free Flight resulted in average savings of 0.63%, 0.77%, and 2.67%, respectively. In 2005, RVSM, RVLSM, RVHSM, and Free Flight

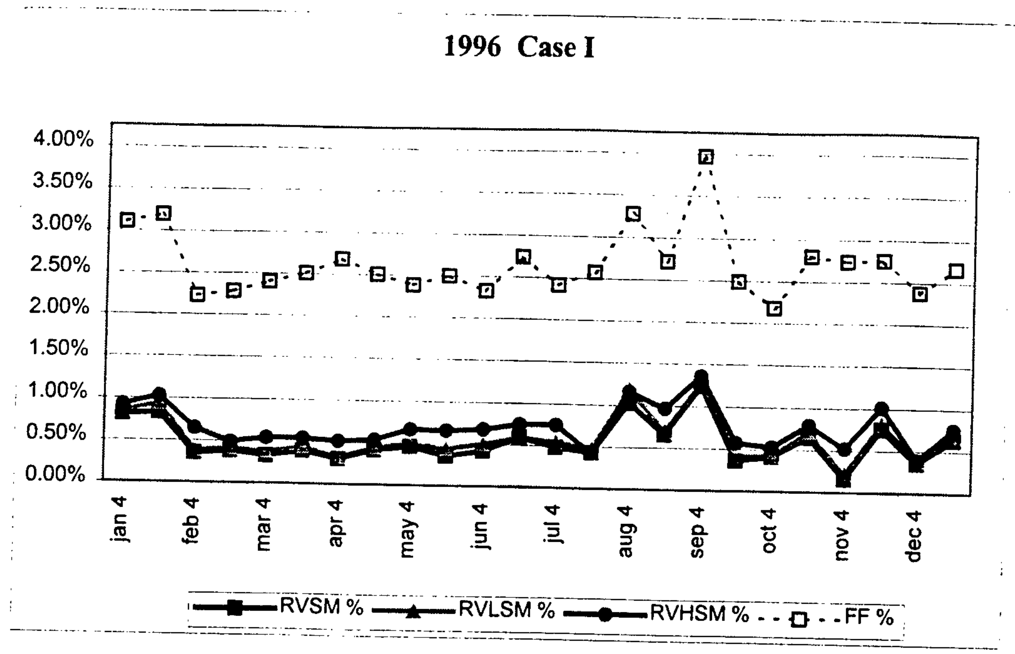


Figure 41. Case I fuel savings results for year 1996.

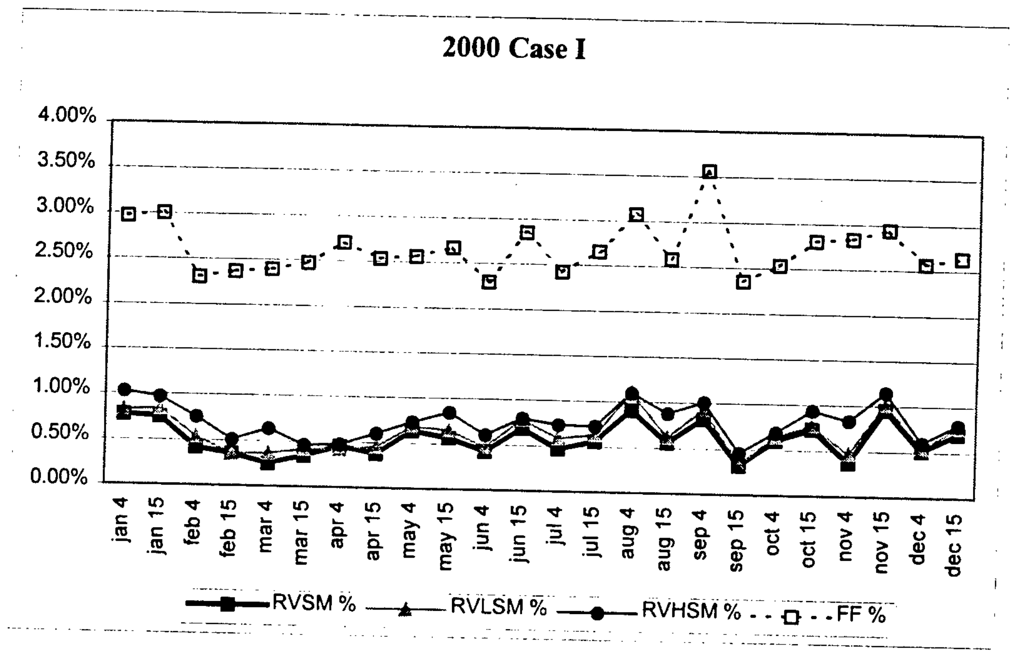


Figure 42. Case I fuel savings results for year 2000.

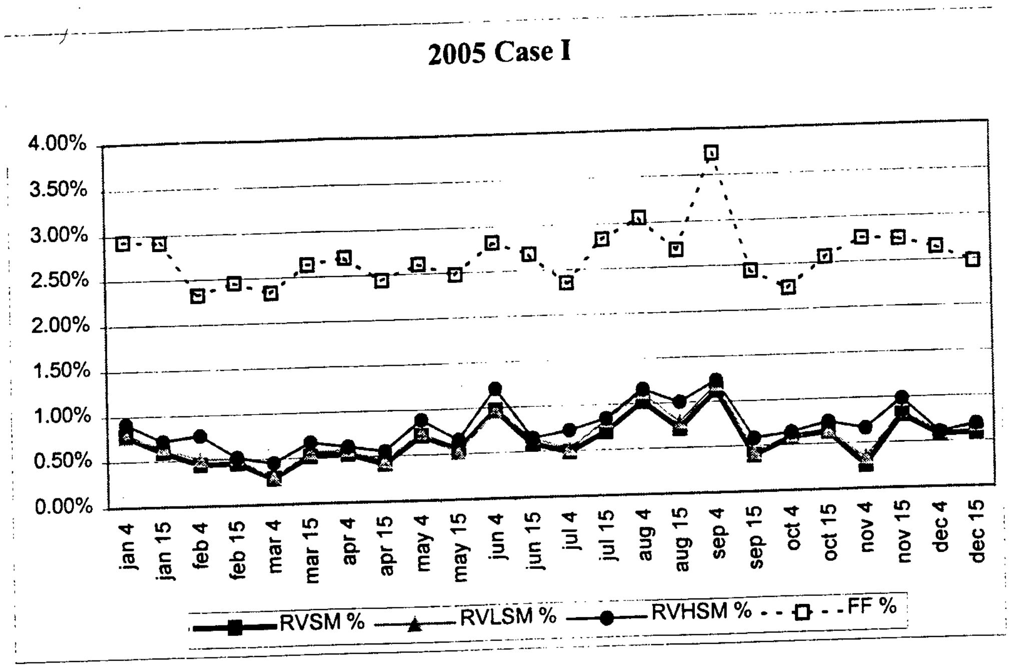


Figure 43. Case I fuel savings results for year 2005.

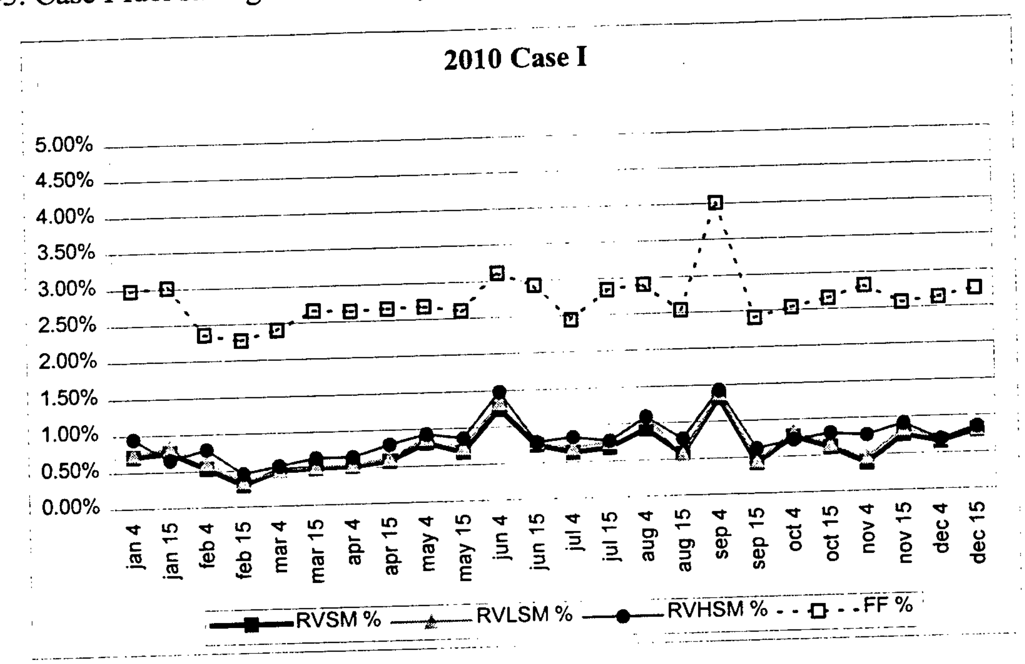


Figure 44. Case I fuel savings results for year 2010.

Table 29. Case I Fuel Results Summary

YEAR	RVSM	RVLSM	RVHSM	Free Flight
1996	0.53%	0.58%	0.71%	2.66%
2000	0.57%	0.63%	0.77%	2.67%
2005	0.61%	0.66%	0.77%	2.66%
2010	0.68%	0.73%	0.84%	2.72%

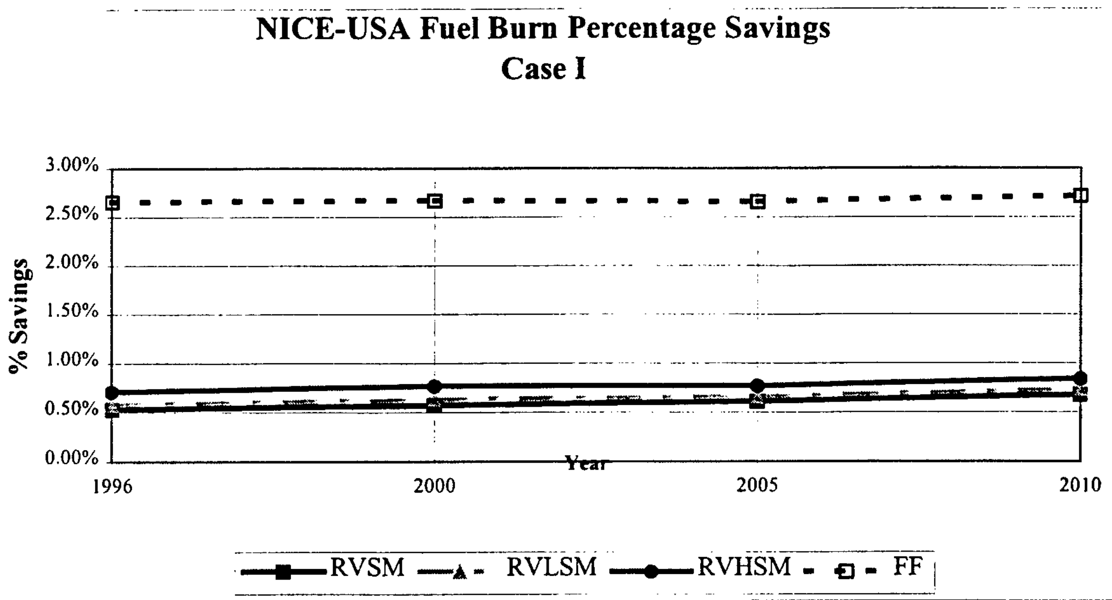


Figure 45. Case I average fuel savings.

showed average fuel savings of 0.61%, 0.66%, 0.77%, and 2.66%, respectively, over baseline. In 2010, RVSM, RVLSM, RVHSM, and Free Flight showed average fuel savings of 0.68%, 0.73%, 0.84%, and 2.72%, respectively, over baseline.

The higher traffic levels each year caused the fuel savings to increase from the baseline scenario for that year. For example, during a typical summer day in 1996, an average of 919 flights were expected to operate in the NAT. In 2000, 2005, and 2010, an average of 1092, 1264, and 1408, respectively, flights will cross the NAT on a typical summer day. This will show an expected average increase in traffic for a typical summer day from 1996 of 18.82%, 37.45%, and 53.21%, for 2000, 2005, and 2010, respectively. As the traffic levels increase, and the separations decrease, more aircraft are able to operate in a more optimal airspace.

An important feature of the analysis was the projected change in fleet mix forecasted for future years. As some of the current aircraft types are replaced with more fuel-efficient models in future years, the overall fuel burn was affected. The changes in the fleet used by the NICE-USA model are shown in Table 3.

A dramatic trend towards fuel savings was not realized as expected from year to year due to the change in the aircraft fleet forecast. Although there were more flights operating in the NAT, more fuel efficient aircraft were expected to replace the older and less fuel efficient aircraft (e.g., in 2010, the L1011 and B747-200 are expected to be replaced by the B777 and EA34). This change in fleet forecast had an impact on the results as the percentage of fuel savings from baseline did not increase year to year with the same magnitude of the traffic increase.

In general, the percentage of fuel savings from the baseline system increased with decreasing separation and increasing traffic. However, the RVSM scenario showed the largest initial percentage of increase compared to RVLSM and RVHSM scenarios. Additional analysis of the Case I fuel savings results by aircraft type, NAT region, and by day are presented in Appendix K.

6.1.2 Case II Fuel Savings

The fuel savings results for Case II are shown in Figure 46. In 1996, the RVSM scenario resulted in an average saving of 0.56% from the baseline, whereas RVSLM, RVHSM, and Free Flight resulted in average savings of 0.65%, 0.79%, and 2.73%, respectively. Full details of the Case II fuel savings results are presented in Appendix L.

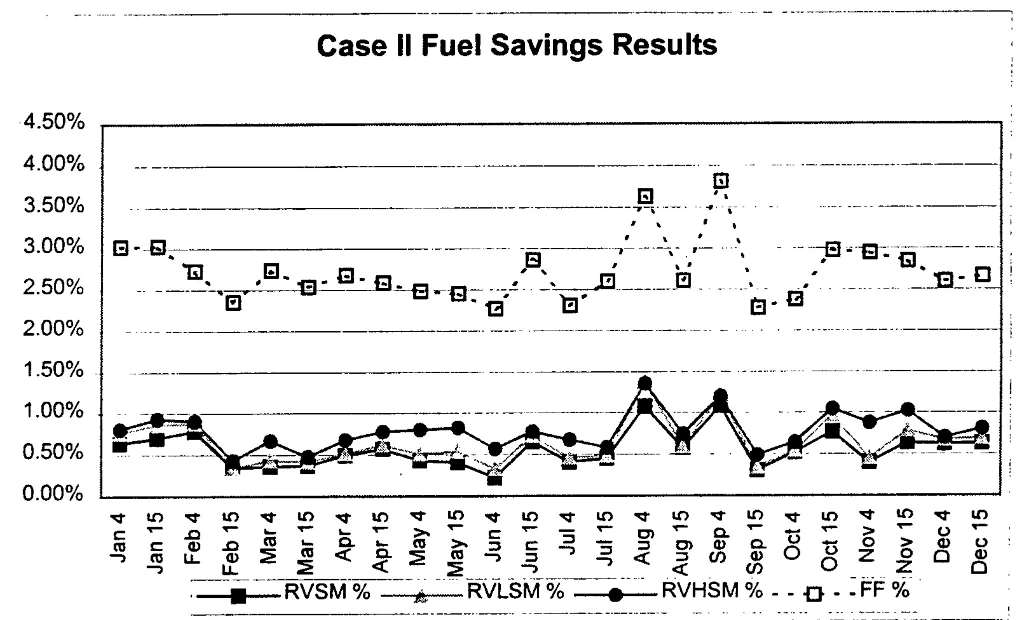


Figure 46. Case II fuel savings results.

Table 30 and Figure 47 show the average fuel savings by direction as well as the average for the two directions.

Table 30. Case II Average Fuel Savings by Direction

Scenario	Eastbound	Westbound	Total
RVSM	0.65%	0.49%	0.56%
RVLSM	0.77%	0.54%	0.65%
RVHSM	0.90%	0.69%	0.79%
Free Flight	2.33%	3.07%	2.73%

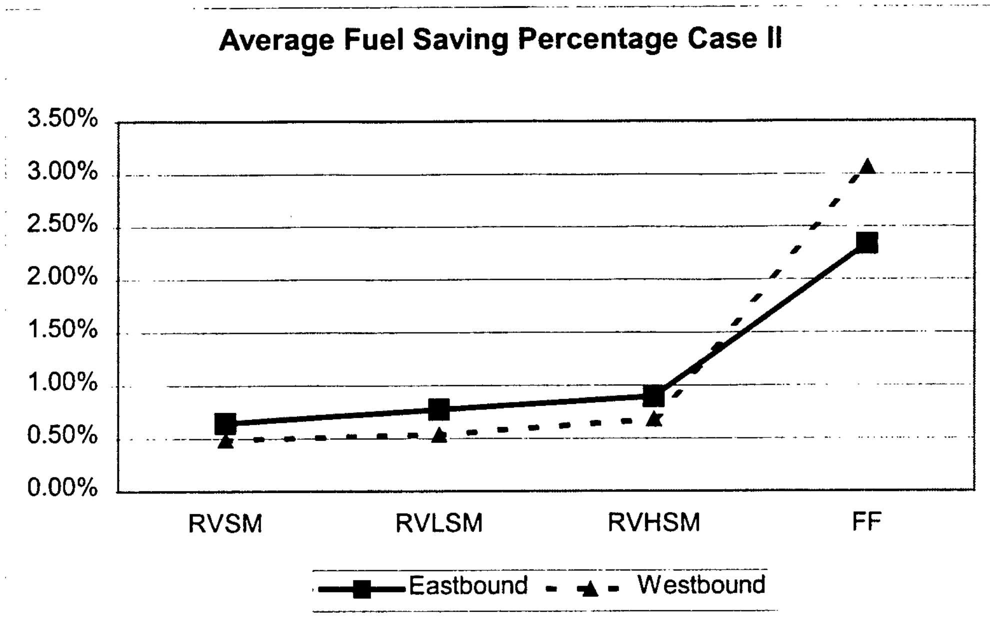


Figure 47. Average fuel savings results by direction case II.

The low, medium, and high traffic days are March 4, October 15, and August 4, respectively. The Lido scenario take-off weights were used in the simulation of these 3 days. Baseline and Free flight used their respective scenario take-off weights from Lido. The RVSM scenario take-off weights were used in the RVSM, RVLSM, and RVHSM scenarios.

Lido generated the take-off weight based on the payload, weather conditions, and scenario. Aircraft operating in more fuel efficient systems such as Free Flights will need less fuel on board than aircraft operating in less fuel efficient systems such as the baseline system. With less fuel on board, an aircraft optimal flight path may be slightly different than it would be with a heavier load. For example, the March 4th take-off weights for the RVSM and Free Flight scenario decreased from the baseline take-off weights by 0.022%, and 0.308%, respectively. For August 4th, the decrease in take-off weights from baseline for RVSM and Free Flight were 0.048% and 0.107%, respectively. For October 15th, the decrease in take-off weights from baseline for

RVSM and Free Flight were 0.010% and 0.047%, respectively. The fuel savings results for the low, medium, and high traffic level days are shown in Table 31.

Table 31. Low, Medium and High Traffic Fuel Savings Results

	Date	No. Of Commercial Flights	RVSM	RVLSM	RVHSM	FF
Low	**3/4/96**	695	0.37%	0.43%	0.67%	2.74%
Medium	**10/15/96**	828	0.77%	0.97%	1.05%	2.98%
High	**8/4/96**	1060	1.08%	1.37%	1.36%	3.63%

Both the eastbound and westbound traffic realized the largest initial increase in fuel savings in the RVSM system as compared to RVLSM and RVHSM. The results indicated a slightly larger average fuel benefit for the eastbound traffic in RVSM, RVLSM, and RVHSM than for the westbound. The most important contributor to the average fuel savings by direction was the daily weather conditions. This is shown in Figure 48, which presents the eastbound and westbound traffic fuel savings from baseline in the RVSM scenario.

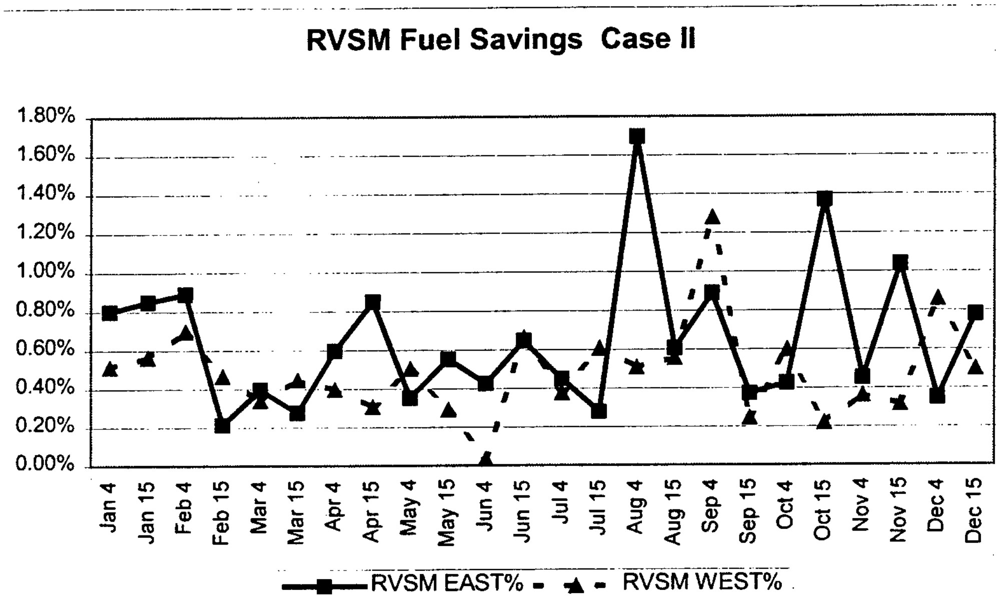


Figure 48. Case II RVSM fuel savings by direction.

Figures 49 and 50 contain the details of the fuel savings percentage results for eastbound and westbound flights, respectively.

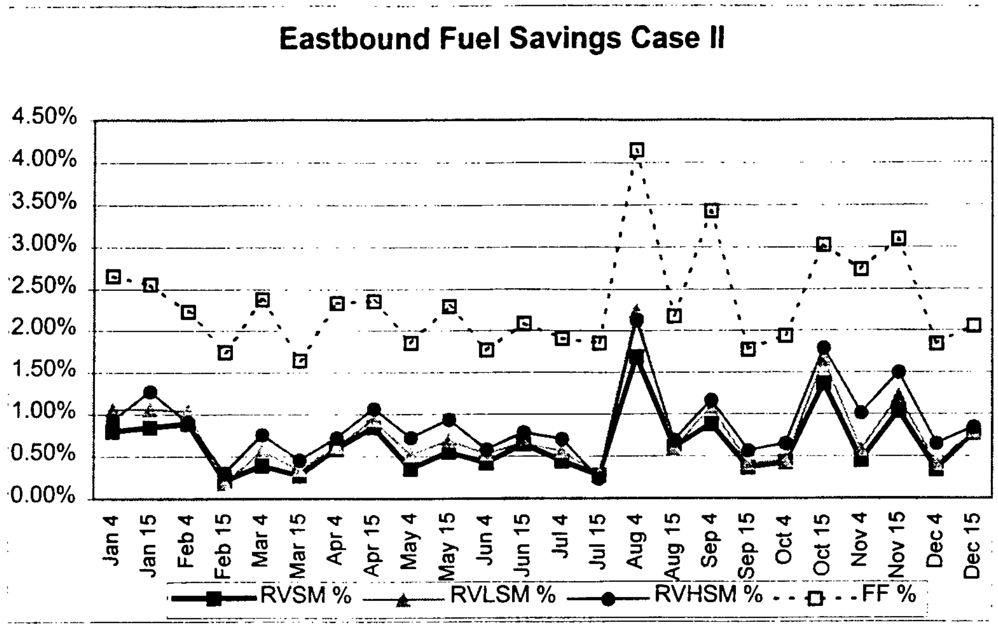


Figure 49. Fuel savings for eastbound flights (case II).

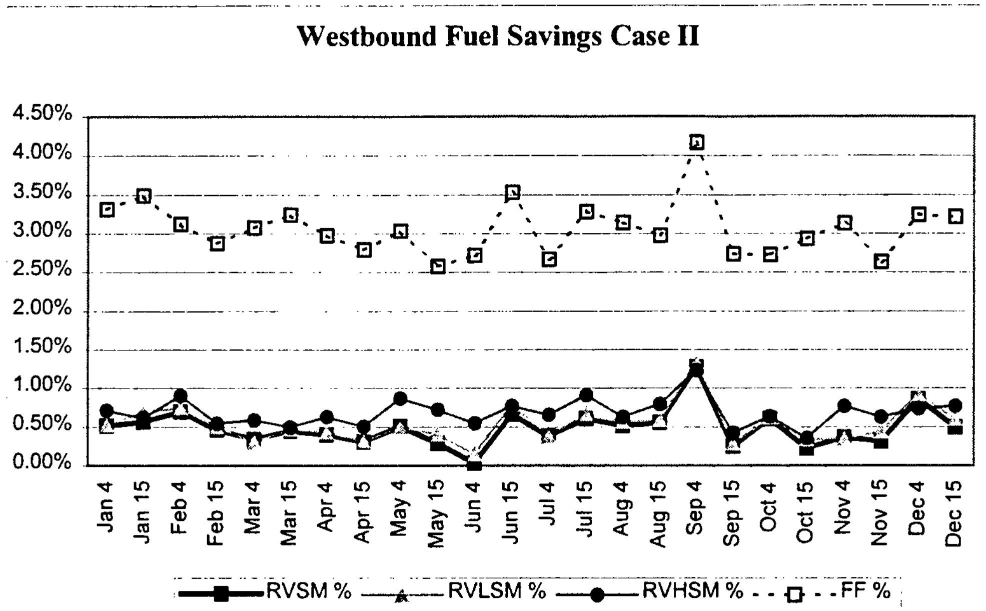


Figure 50. Fuel savings for westbound flights (case II).

The fuel savings for eastbound and westbound flights depend on the weather conditions, aircraft type, and separation scenario. In general, eastbound aircraft can achieve a higher NAT entry flight level than the westbound flights. The initial higher entry flight levels along with the decrease in separations provide more available optimal airspace for the eastbound flights. Westbound aircraft leaving Western Europe cannot initially achieve a high NAT entry flight level. The requests for lower entry flight levels create competition among westbound flights for optimal flight levels. The decreases in separations are accounted for, but the full benefit of the

vertical reduction is not realized due to the close proximity of Western Europe airports to the NAT MNPS boundary.

6.2 Communication Volume

Communication volume for the scenarios was calculated in the FTM. It was measured by the number of communications between the aircraft and the ATCSs. These transmissions reflect the waypoint crossings (mandatory position reporting points) and requests for step climbs and the step-climb replies. The communication counts were totaled for each simulation day in Case I and Case II, and the results are shown in Tables 32 and 33, respectively.

Table 32. Communication Totals for Case I

Year	Scenario	No. Of Communications	Percentage Difference
1996	Baseline	127672	
1996	RVSM	129096	-1.12%
1996	RVLSM	129083	-1.11%
1996	RVHSM	129460	-1.40%
1996	Free Flight	122238	4.26%
2000	Baseline	151282	
2000	RVSM	152907	-1.07%
2000	RVLSM	152856	-1.04%
2000	RVHSM	153082	-1.19%
2000	Free Flight	144956	4.18%
2005	Baseline	174129	
2005	RVSM	176070	-1.11%
2005	RVLSM	176113	-1.14%
2005	RVHSM	176406	-1.31%
2005	Free Flight	166715	4.26%
2010	Baseline	194703	
2010	RVSM	196752	-1.05%
2010	RVLSM	196867	-1.11%
2010	RVHSM	197023	-1.19%
2010	Free Flight	186531	4.20%

Table 33. Communication Totals for Case II

Year	Scenario	No. Of Communications	Percentage Difference
1996	Baseline	127708	
1996	RVSM	129129	-1.11%
1996	RVLSM	129089	-1.08%
1996	RVHSM	131007	-2.58%
1996	Free Flight	122298	4.24%

The Percentage Difference column was calculated as (Baseline – Scenario) / Baseline * 100%. The total counts for Free Flight communication were always lower than baseline. This was because communication total for Free Flight included the waypoint crossings only. A step-climb in the Free Flight scenario did not require ATC clearance. Requests for step climbs were not made during the Free Flight scenario. Because there was no step-climb request made and no replies to the step-climb requests made in the Free Flight scenario.

The average increase in the number of communication counts from Baseline for RVSM, RVLSM, and RVHSM were 1.09%, 1.10%, and 1.53%, respectively. The increase in the number of communication counts in the RVSM, RVLSM, and RVHSM scenarios was attributed to the differences in the flight plans generated in the FPM. The same flight in the Baseline, RVSM, and RVHSM scenarios may contain a different number of step climbs and reporting points.

The increase in the number of communications from year to year was due to the increase in traffic volume. As more aircraft utilized the oceanic airspace, the communication task load increased for the ATCSs under the current HF communication infrastructure in place across most of the NAT airspace.

6.3 Step-Climbs Requested and Granted

Step-climbs requests were initiated at least 15 minutes before an aircraft reached a waypoint crossing during the oceanic portion of flight. An aircraft could initiate a step-climb request when the current flight level was lower than that specified in the original flight plan. A step climb was not permitted at the oceanic exit point. The total number of step climbs requested and granted for Case I and Case II are shown in Tables 34 and 35 respectively.

The Percentage Difference columns represent the percentage change from the Baseline scenario and were calculated as (Baseline – Scenario) / Baseline * 100%. The number of step-climb requests made was controlled within the model. All scenarios, except Free Flight, had a probability of 4% for step-climb requests. If a flight was operating at a lower flight level than indicated in the original flight plan, a random number between zero and one was generated. A request for a step-climb was made if the generated random number was less than 0.04. In the Free Flight scenario, requests for step climbs were not made, flight level changes were performed by all flights as specified in the flight plan.

Table 34. Case I Step-Climb Results

Year	Scenario	Step Climbs Requested	% Difference (Requested)	Step Climbs Granted	% Difference (Granted)
1996	Baseline	2717		1294	
1996	RVSM	3189	-17.37%	1753	-35.47%
1996	RVLSM	3182	-17.11%	1848	-42.81%
1996	RVHSM	3354	-23.44%	2067	-59.74%
2000	Baseline	3163		1451	
2000	RVSM	3740	-18.24%	2042	-40.73%
2000	RVLSM	3715	-17.45%	2106	-45.14%
2000	RVHSM	3834	-21.21%	2391	-64.78%
2005	Baseline	3707		1655	
2005	RVSM	4217	-13.76%	2192	-32.45%
2005	RVLSM	4241	-14.41%	2367	-43.02%
2005	RVHSM	4446	-19.94%	2662	-60.85%
2010	Baseline	4086		1779	
2010	RVSM	4728	-15.71%	2456	-38.06%
2010	RVLSM	4784	-17.08%	2638	-48.29%
2010	RVHSM	4886	-19.58%	2874	-61.55%

Table 35. Case II Step-Climb Results

Year	Scenario	Step Climbs Requested	% Change (Requested)	Step Climbs Granted	% Change (Granted)
1996	BASELINE	2705		1253	
1996	RVSM	3218	-18.96%	1767	-41.02%
1996	RVLSM	3199	-18.26%	1822	-45.41%
1996	RVHSM	4133	-52.79%	2237	-78.53%

The average increase in the number of step-climb requests for RVSM, RVLSM, and RVHSM was 16.81%, 16.86%, and 27.39% respectively. The RVSM and RVLSM scenarios utilized the same flight plans in the FTM. Differences in the scenario flight plans accounted for the increase in step-climb requests within the same year. The increase in the number of step-climbs requested from year to year was attributed to the increase in traffic.

The number of step-climbs granted increased from the Baseline scenario by an average of 37.55% in the RVSM scenario, 44.93% in the RVLSM scenario, and 65.09% in the RVHSM scenario. A step-climb was granted if the change in flight level did not result in a conflict with another aircraft. As more airspace becomes available with decreasing separation standards, the number of step climbs granted also increased.

6.4 Conflicts Detected and Resolved

The conflicts detected and resolved for Case I and Case II are shown in Tables 36 and 37 respectively.

Table 36. Case I Conflicts Detected and Resolved

Year	Scenario	Conflicts Detected	% Difference (Detected)	Conflicts Resolved	% Difference (Resolved)
1996	Baseline	9769		38541	
1996	RVSM	7840	19.75%	21839	43.34%
1996	RVLSM	6788	30.51%	16125	58.16%
1996	RVHSM	5173	47.05%	34107	11.50%
2000	Baseline	11992		51221	
2000	RVSM	9638	19.63%	28352	44.65%
2000	RVLSM	8312	30.69%	21192	58.63%
2000	RVHSM	6313	47.36%	40681	20.58%
2005	Baseline	14635		63936	
2005	RVSM	11642	20.45%	32933	48.49%
2005	RVLSM	10096	31.01%	25357	60.34%
2005	RVHSM	7998	45.35%	49644	22.35%
2010	Baseline	16686		77234	
2010	RVSM	13517	18.99%	41307	46.52%
2010	RVLSM	12139	27.25%	29809	61.40%
2010	RVHSM	8966	46.27%	57037	26.15%

Table 37. Case II Conflicts Detected and Resolved

Year	Scenario	Conflicts Detected	% Difference (Detected)	Conflicts Resolved	% Difference (Resolved)
1996	Baseline	10482		45181	
1996	RVHSM	7774	25.83%	40204	11.02%
1996	RVLSM	7860	25.01%	21245	52.98%
1996	RVSM	9013	14.01%	30293	32.95%

The Percentage Difference columns represent the percentage difference from the Baseline scenario. They were calculated as (Baseline - Scenario) / Baseline * 100%. The positive values in the Percentage Difference columns indicated a decrease from the Baseline scenario. The number of conflicts detected was the number of potential conflicts that the model detects from the original flight plan. The number of conflict resolutions was the number of iterations performed to solve the conflict detection. There could be many conflict resolutions performed to resolve one conflict as described in Section 4.4.1.

The average decrease in the number of conflicts detected from Baseline for RVSM, RVLSM, and RVHSM was 18.57%, 28.90%, and 42.37%, respectively. The results illustrated that increasing the amount of available airspace reduced the number of conflicts that existed in the original Baseline separation system. In the Free Flight scenario, the aircraft executed their optimal flight plans without regard to other aircraft in the system. The conflict detection algorithm was turned off in the Free Flight system, therefore the number of conflicts detected was not reported for Free Flight.

The average decrease in the number of conflict resolutions from Baseline for RVSM, RVLSM, and RVHSM were 43.19%, 58.30%, and 18.32%, respectively. The decrease in conflict resolutions was caused by the increase in the available airspace. The decrease for the RVHSM scenario was smaller than that of the RVSM and RVLSM scenarios. This was caused by the reduction in the lateral separation. The lateral separation reduction required additional steps in the RVHSM scenario conflict resolution decision tree. In this scenario, increasing the available airspace allowed for more choices in the reclearance procedures, potentially increasing the number of reclearance attempts.

6.5 Summary of Results

Table 38 summarizes the results presented in Section 6. They represent the percentage difference from the Baseline System. It was calculated as (Baseline – Scenario) / Scenario * 100%. Therefore, a positive value indicated a decrease from the Baseline System and a negative value indicated an increase from the Baseline System. The summary represents the average change to the performance measures for 1996, 2000, 2005, and 2010 for Case I and Case II.

Table 38. Summary of Results (Average of All Years)

Performance Measure	RVSM	RVLSM	RVHSM	Free Flight
Fuel Consumption	0.59%	0.65%	0.78%	2.69%
Communication	-1.09%	-1.10%	-1.53%	4.23%
Conflicts Detected	18.57%	28.89%	42.37%	-
Conflict Resolutions	43.19%	58.30%	18.32%	-
Step Climbs Granted	-37.55%	-44.93%	-65.09%	-

The average fuel savings for each year is summarized in Table 39 and Figure 51.

Table 39. Summary of Fuel Savings Results by Year and Scenario

YEAR	RVSM	RVLSM	RVHSM	Free Flight
1996	0.55%	0.62%	0.75%	2.69%
2000	0.57%	0.63%	0.77%	2.67%
2005	0.61%	0.66%	0.77%	2.66%
2010	0.68%	0.73%	0.84%	2.72%

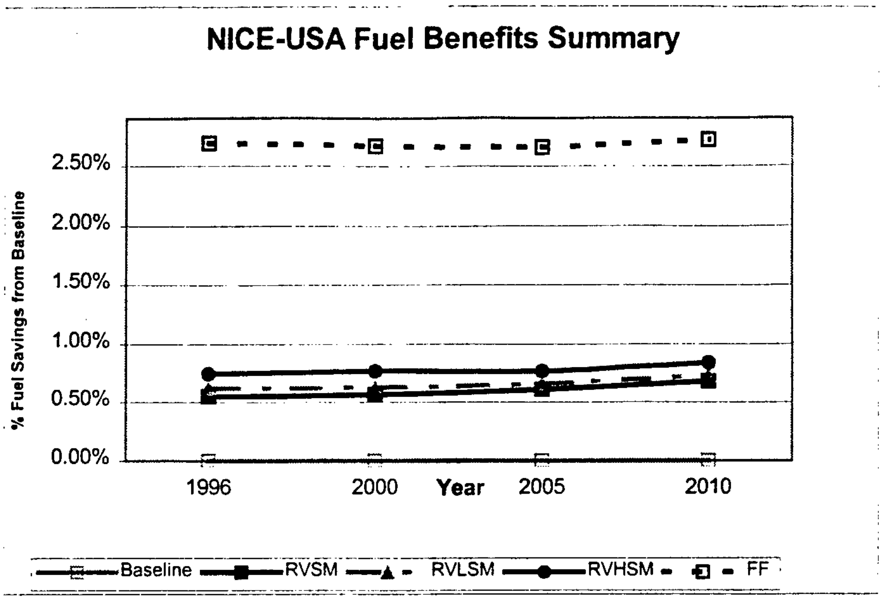


Figure 51. Fuel savings results by year and scenario.

7. Conclusions

This report highlights the results of the NICE-USA simulation efforts. Fuel burn results obtained from three reduced separation scenarios (RVSM, RVLSM, and RVHSM) and the Free Flight scenario were compared to results obtained for the Baseline System. Key assumptions have also been summarized.

The key results from this study can be summarized as follows:

- The reduced separation systems, RVSM, RVLSM, RVHSM, and Free Flight, achieved fuel savings when compared to the Baseline System. The mean fuel burn savings ranged from 0.55% in 1996 to 0.84% in 2010.
- The largest contribution to this fuel saving is likely to be realized from the implementation of full RVSM. Modeling shows this initiative saved between 0.5% of total fuel in 1996 and 0.7% of total fuel in 2010 compared to the Baseline System.
- Further fuel savings over RVSM were shown to be approximately 0.1% of total fuel for RVLSM and 0.2% of total fuel for RVHSM.
- The Free Flight scenario results showed a mean fuel burn savings over the Baseline System of approximately 2.68%. This was approximately 1.9% over the saving achievable by the implementation of RVHSM. It must be emphasized that the Free Flight scenario is a "theoretical best case" scenario and that the savings cannot be fully attained in the real world.
- Overall, a trend was observed for fuel savings to increase from year to year with growth in traffic volume. This rate appeared to be constant, despite older, less efficient aircraft types being replaced by newer aircraft types in 2005 and 2010.

- In all separation scenarios (RVSM, RVLSM, and RVHSM), the ATC communication loadings increased with increasing traffic. The increase in ATC communications from the Baseline System ranged from approximately 1% for RVSM to 1.5% for RVHSM. This increase was attributed to the additional number of step climbs granted in the reduced separation scenarios.
- A decrease in ATCS' conflict detection and resolution activities was realized in all separation scenarios (RVSM, RVLSM, and RVHSM) when compared to the Baseline System. The decrease in the ATCS conflict detection activities from the Baseline System ranged from approximately 18% for RVSM to 42% for RVHSM. This decrease was caused by the increase in the amount of available airspace for flight re-clearance.

The scenario fuel savings results were affected by the step-climb assumptions made in the simulation. The probability for a step-climb request was held constant at a low value for all the separation scenarios (RVSM, RVLSM, and RVHSM), except in Free Flight where 100% of step climbs were made. The probability was set to reflect the current HF communication infrastructure across most of the NAT airspace. This assumption was made due to uncertainties regarding human performance and the ATC communication capability in future years and in the reduced separation systems. Improvements made in ATCS' communication capabilities may result in an increase in step-climb services. This in turn would increase the amount of fuel savings when compared to the current ATC structure in the model.

There were many factors other than the separation scenarios affecting the fuel results. These factors included the ATC communication efficiencies (affecting step climbs), reclearance procedures, aircraft scenario take-off weights, fleet forecasts, and the OTS. Assumptions were made in this study regarding these factors. Further investigation into these factors will be needed to determine their significance. A designed experiment approach will be used to determine the relative significance of each factor.

Acronyms

ATC	Air Traffic Control
ATCS	Air Traffic Control Specialist
ATM	Air Traffic Management
ATMIP	Air Traffic Management Implementation Plan
CTA	Control Area
DOT	Department of Transportation
FAA	Federal Aviation Administration
FE Real	Real Flight Events
FE Stat	Statistically generated Flight Events
FF	Free Flight
FIR	Flight Information Region
FL	Flight Level
GAATS	Gander Automated Air Traffic System
GMT	Greenwich Mean Time
HF	High Frequency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICE	Iceland
IMG	Implementation Management Group
INATSIM	Integrated North Atlantic Air Traffic Simulation Model
Lido	Lido GmbH Lufthansa Aeronautical Services
MET	Meteorological
MNPS	Minimum Navigation Performance Specification
MTT	Minimum Time Track
NAT	North Atlantic
NICE Task Force	NAT IMG Cost/Effectiveness Program
NICE-ICE	NICE Task Force from Iceland (Icelandic CAA, University of Iceland)
NICE-UK	NICE Task Force from the United Kingdom (UK NATS)
NICE-USA	NICE Task Force from the United States (FAA, Rutgers University)
nm	Nautical Miles
NWS	National Weather Service
OACC	Oceanic Area Control Center
OTS	Organized Track System
RVHSM	Reduced Vertical and Horizontal Separation Minimum
RVLSM	Reduced Vertical and Longitudinal Separation Minimum
RVSM	Reduced Vertical Separation Minimum
TFG	Traffic Forecasting Group
UK	United Kingdom
UK NATS	UK National Air Traffic Services LTD

References

1. Burt, L., May, N.A., "NATRACK Model Verification Report", Civil Aviation Authority, Chief Scientist's Division, National Air Traffic Services, November 1993.

2. Couluris, G.J., Conrad B., "Oceanic Area System Improvement Study (OASIS) Volume I: Executive Summary and Improvement Alternatives Development and Analysis", Federal Aviation Administration, Report No. FAA-EM-81-17.I, September 1981.

3. Couluris G. J., "Oceanic Area System Improvement Study (OASIS), Volume II: North Atlantic Region Air Traffic Services System Description", Federal Aviation Administration, Report No. FAA-EM-81-17.II, September 1981.

4. Federal Aviation Administration, "Strategic Plan for Oceanic Airspace Enhancements and Separation Reductions", September 1998.

5. International Civil Aviation Organization, "Simulated Effects of 1000 Ft. Vertical Separation Minimum On Occupancy", Presented by Canada, North Atlantic Systems Planning Group Twenty Ninth Meeting, June 1993.

6. International Civil Aviation Organization, "Simulated Effects of 1000 Ft. Vertical Separation Minimum On Occupancy", Presented by Canada, North Atlantic Systems Planning Group Thirtieth Meeting, June 1994.

7. Jane's Information Group, *Jane's All the World Aircraft, 1996*, Janes Information Group Limited, 1996.

8. Livingston, D., Strazzerri, A., & Baart D., "Application of Composite Separation to the North Pacific Track System", Federal Aviation Administration, Report No. DOT/FAA/CT-TN83/34, June 1984.

9. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Report of the NICE Task Force", October 1999

10. *North Atlantic Traffic Allocation Model Users Manual*, Transport Canada, 1991.

11. Personal Communication with Mr. Manfred Clasen, Lufthansa, Germany, February 1996.

12. Prince, J.P., "Verification of the NATRACK Model - Contracted Amendments March 1994", Civil Aviation Authority, Department of Research Systems and Planning, Chief Scientist's Division NATS, March, 1994.

13. Wagenmakers, Joop, *Aircraft Performance Engineering*, Prentice Hall, 1991.

Bibliography

1. *Air Traffic Control 7110.65H*, U.S. Department of Transportation, Federal Aviation Administration, September 1993.

2. Atkinson, B.W., *Weather, Reviews of United Kingdom Statistical Sources*, 1985, Pergamon Press, New York.

3. Bellman, Richard E., Dreyfus, Stuart E., *Applied Dynamic Programming*, Princeton University Press, 1962.

4. Bertin, John, J., Smith, Michael L., *Aerodynamics For Engineers, Second Edition*, Prentice Hall, 1989.

5. Burt, L., May, N.A., "NATRACK Model Verification Report", Civil Aviation Authority, Chief Scientist's Division, National Air Traffic Services, November 1993.

6. Civil Aviation Authority, Directorate of Operational Research and Analysis Chief Scientist's Division, "An Assessment of the Economic Benefits and Safety Implications of Reduced Separation in North Atlantic Region", December 1990.

7. Collins, B., Ford, D., "Concepts for Aviation Fuel Efficiency", Mitre Corporation and the Federal Aviation Administration, October 23, 1984.

8. Collins, B., "Estimation of Aircraft Fuel Consumption", *Journal of Aircraft*, Vol. 19, No. 11, November 1982.

9. Conrad B., "Oceanic Area System Improvement Study (OASIS) Volume VI: North Atlantic, Central East Pacific, and Caribbean Regions Navigation Systems Description", Federal Aviation Administration, Report No. FAA-EM-81-17. VI, September 1981.

10. Conrad, B., "Oceanic Area System Improvement Study (OASIS) Volume V: North Atlantic, Central East Pacific, and Caribbean Regions Communication Systems Description", Federal Aviation Administration, Report No. FAA-EM-81-17.V, September 1981.

11. Couluris, G.J., Conrad B., "Oceanic Area System Improvement Study (OASIS) Volume I: Executive Summary and Improvement Alternatives Development and Analysis", Federal Aviation Administration, Report No. FAA-EM-81-17.I, September 1981.

12. Couluris G. J., "Oceanic Area System Improvement Study (OASIS), Volume II: North Atlantic Region Air Traffic Services System Description", Federal Aviation Administration, Report No. FAA-EM-81-17.II, September 1981.

13. Elsayed, E.A., Summerill, S., "Generation of Flight Events for the Air Traffic Over the North Atlantic Ocean", Rutgers University, Department of Industrial and Systems Engineering, IE Working Paper No. 115, 1997.

14. Federal Aviation Administration, "Considerations On Collision Risk Analysis For Decision Making In The NAT Region.", Report No. FAA-CT-81-36, March 1981.

15. Federal Aviation Administration, "Strategic Plan for Oceanic Airspace Enhancements and Separation Reductions", September 1998.

16. Department of Transportation, Federal Aviation Administration, National Oceanic and Atmospheric Administration, *Aviation Weather*, 1975 edition.

17. Gerhardt C.M., "Modeling of the Air Traffic Activity and Separation Minima Over the North Atlantic Ocean", Master Thesis No. 88, Rutgers University, Department of Industrial and Systems Engineering, May 1997.

18. Hubin, W., *The Science of Flight, Pilot-Oriented Aerodynamics*, Iowa State University Press, 1992.

19. International Civil Aviation Organization, "Simulated Effects of 1000 Ft. Vertical Separation Minimum On Occupancy", Presented by Canada, North Atlantic Systems Planning Group Twenty Ninth Meeting, June 1993.

20. International Civil Aviation Organization, "Simulated Effects of 1000 Ft. Vertical Separation Minimum On Occupancy", Presented by Canada, North Atlantic Systems Planning Group Thirtieth Meeting, June 1994.

21. Jane's Information Group, *Jane's All the World Aircraft, 1996*, Janes Information Group Limited, 1996.

22. Law, W., Kelton, D. and Averill, M., *Simulation Modeling and Analysis*, Second Edition, McGraw-Hill, Incorporated 1991.

23. Livingston, D., Strazzerri, A., & Baart D., "Application of Composite Separation to the North Pacific Track System", Federal Aviation Administration, Report No. DOT/FAA/CT-TN83/34, June 1984.

24. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/4)", February 27-29, 1996.

25. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/5)", September 3-5, 1996.

26. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/6)", November 25-26, 1996.

27. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/7)", March 1997.

28. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/8)", July 1997

29. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/9)", November 1997

30. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/10)", May 1998

31. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/11)", October 1998

32. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/12)", March 1999

33. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Nice Task Force Summary Report", April 1999.

34. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Nice Task Force Technical Report (Version 1.0)", April 1999.

35. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Notes of NICE Technical Review Meetings (NICE/13)", September 1999

36. North Atlantic Implementation Management Group Cost Effectiveness Task Force (NAT IMG Cost Effectiveness or NICE Task Force), "Report of the NICE Task Force", October 1999

37. North Atlantic Implementation Management Group (NAT IMG), "Summary of Discussions of the Sixth Meeting of the North Atlantic Implementation Management Group (NAT IMG/6) of the North Atlantic Systems Planning Group (NAT SPG)", May 13-17, 1996.

38. *North Atlantic MNPS Airspace Operations Manual, Eighth Edition*, North Atlantic Systems Planning Group, April 1999.

39. *North Atlantic Traffic Allocation Model Users Manual*, Transport Canada, 1991.

40. North Atlantic Traffic Forecasting Group, "North Atlantic Air Traffic Forecasts for the Years 1994-2000, 2005 and 2010", 29th Meeting, May 1995.

41. Paglione M., "Modeling of the Air Traffic Activity Over the North Atlantic Ocean", Masters Thesis No. 85, Rutgers University, Department of Industrial and Systems Engineering, October 1996.

42. Paulson, G., "A Review of U.K. Benefit Studies of North Atlantic Traffic Structures Since 1987", Presented by the United Kingdom, International Civil Aviation Organization, November 9, 1990.

43. Personal Communication with Mr. Manfred Clasen, Lufthansa, Germany, February 1996.

44. Prince, J.P., "Verification of the NATRACK Model - Contracted Amendments March 1994", Civil Aviation Authority, Department of Research Systems and Planning, Chief Scientist's Division NATS, March, 1994.

45. Prince J.P., "An Overview of NATSIM: The North Atlantic Simulation Model", National Air Traffic Services Ltd, London, R&D Report 9741, 1997.

46. Prince J.P., Simonsson P., Bass J., "North Atlantic Reduced Horizontal Separation Minima – RHSM Phase 3: Fuel Burn Benefits and Segregated Airspace Design", National Air Traffic Services Ltd, London, R&D Report 9814, 1998.

47. Schriber, T., *An Introduction to Simulation Using GPSS/H*, John Wiley and Sons, 1991.

48. Tomasky, D.J., "Reliability And Performance Modeling Of Telecommunication Networks For Air Traffic Control of Oceanic Airspace", Master Thesis No. 79, Rugters University, Department of Industrial and Systems Engineering, October 1994.

49. Taylor, George B., *Aeronautical Meteorology*, 1940 Pitman Publishing Corporation, New York.

50. Wagenmakers, Joop, *Aircraft Performance Engineering*, Prentice Hall, 1991.

51. Wang, K., D'Esopo, D., "Oceanic Area System Improvement Study (OASIS) Volume IX: Flight Cost Model Description", Federal Aviation Administration, Report No. FAA-EM-81-17.IX, September 1981.

52. Winston, Wayne L., *Operations Research: Applications and Algorithms*, Duxbury Press, 1987.

Appendix A

NAT TFG Traffic Forecast by Regional Pairing, Season and Year (In Percent %)

Summer	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
AFR-NAM/CAR/BER	0.85	0.76	0.67	0.53	0.63	0.73	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.57
EUR-NAM/EAST	51.28	50.85	50.42	51.49	50.81	50.12	49.64	49.49	49.35	49.21	49.09	48.97	48.86	48.75
EUR-NAM/MIDWEST	15.07	15.74	16.42	15.29	15.90	16.52	16.94	17.32	17.68	18.02	18.33	18.63	18.91	19.17
EUR-NAM/WEST	7.49	7.60	7.71	7.73	7.77	7.82	7.98	8.06	8.14	8.22	8.29	8.36	8.42	8.48
EUR/SCAN-CAR/BER	10.43	9.86	9.30	9.58	10.19	10.80	11.06	11.23	11.38	11.53	11.66	11.79	11.91	12.02
EUR/SCAN/IBE-NAM/ALASKA	0.76	0.63	0.50	0.97	0.81	0.64	0.63	0.61	0.59	0.57	0.55	0.54	0.52	0.51
IBE-CAN	0.85	0.93	1.01	0.97	0.85	0.73	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.57
IBE-CAR	2.65	2.46	2.26	2.28	2.39	2.50	2.44	2.35	2.28	2.21	2.14	2.08	2.02	1.96
IBE-USA/BER	4.08	4.26	4.44	4.39	4.13	3.87	3.77	3.65	3.53	3.42	3.31	3.22	3.12	3.04
SCAN-NAM	6.54	6.91	7.29	6.77	6.53	6.29	6.13	5.92	5.73	5.55	5.38	5.23	5.08	4.93
Winter	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
AFR-NAM/CAR/BER	0.91	0.77	0.62	0.86	0.81	0.75	0.73	0.70	0.67	0.65	0.63	0.61	0.59	0.57
EUR-NAM/EAST	53.75	53.93	54.11	54.09	53.60	53.10	52.59	52.54	52.50	52.46	52.42	52.38	52.35	52.32
EUR-NAM/MIDWEST	13.30	14.04	14.78	14.76	14.48	14.19	14.60	14.83	15.05	15.26	15.44	15.62	15.78	15.94
EUR-NAM/WEST	6.59	6.63	6.66	6.79	6.87	6.95	7.07	7.18	7.27	7.36	7.45	7.52	7.60	7.66
EUR/SCAN-CAR/BER	11.70	10.64	9.57	9.70	10.91	12.12	12.51	12.72	12.92	13.10	13.28	13.44	13.58	13.72
EUR/SCAN/IBE-NAM/ALASKA	0.91	0.77	0.62	0.97	0.86	0.75	0.73	0.71	0.70	0.69	0.67	0.66	0.65	0.64
IBE-CAN	0.45	0.54	0.62	0.65	0.51	0.38	0.37	0.35	0.34	0.33	0.31	0.30	0.29	0.28
IBE - CAR	2.95	2.57	2.19	2.26	2.49	2.73	2.65	2.54	2.45	2.36	2.27	2.20	2.13	2.06
IBE-USA/BER	3.64	3.80	3.95	3.99	3.64	3.29	3.19	3.07	2.95	2.84	2.74	2.65	2.56	2.48
SCAN-NAM	5.80	6.33	6.87	5.93	5.83	5.73	5.57	5.35	5.15	4.96	4.78	4.62	4.47	4.33

Appendix B

NAT TFG Hourly Traffic Forecast (in Percent) by Year, Season and Direction

Summer Eastbound

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
00:00 - 01:00	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
01:00 - 02:00	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
02:00 - 03:00	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
03:00 - 04:00	17.3	17.3	17.3	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
04:00 - 05:00	14.9	14.9	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.1	15.1
05:00 - 06:00	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
06:00 - 07:00	7.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.6	7.6
07:00 - 08:00	6.2	6.2	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4
08:00 - 09:00	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
09:00 - 10:00	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8
10:00 - 11:00	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
11:00 - 12:00	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.0
12:00 - 13:00	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
13:00 - 14:00	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
14:00 - 15:00	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
15:00 - 16:00	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
16:00 - 17:00	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
17:00 - 18:00	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
18:00 - 19:00	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7
19:00 - 20:00	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
20:00 - 21:00	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
21:00 - 22:00	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
22:00 - 23:00	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
23:00 - 24:00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9

Summer Westbound

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
00:00 - 01:00	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
01:00 - 02:00	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
02:00 - 03:00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
03:00 - 04:00	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
04:00 - 05:00	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
05:00 - 06:00	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1
06:00 - 07:00	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
07:00 - 08:00	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
08:00 - 09:00	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
09:00 - 10:00	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
10:00 - 11:00	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.1
11:00 - 12:00	7.2	7.1	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
12:00 - 13:00	13.8	13.8	13.9	13.9	14.0	14.0	14.0	14.1	14.1	14.1	14.2	14.2	14.2	14.3
13:00 - 14:00	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.8	15.8	15.8
14:00 - 15:00	15.6	15.6	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.4	15.4	15.4	15.4
15:00 - 16:00	13.2	13.2	13.3	13.3	13.3	13.4	13.4	13.4	13.4	13.5	13.5	13.5	13.6	13.6
16:00 - 17:00	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.6
17:00 - 18:00	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
18:00 - 19:00	3.7	3.7	3.7	3.7	3.7	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
19:00 - 20:00	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
20:00 - 21:00	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3
21:00 - 22:00	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
22:00 - 23:00	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
23:00 - 24:00	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Winter Eastbound

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
00:00 - 01:00	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
01:00 - 02:00	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
02:00 - 03:00	6.8	6.8	6.8	6.8	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
03:00 - 04:00	17.5	17.5	17.5	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.3	17.3	17.3	17.3
04:00 - 05:00	21.3	21.2	21.2	21.1	21.0	21.0	21.0	21.0	20.9	20.9	20.9	20.8	20.8	20.8
05:00 - 06:00	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.2	14.2
06:00 - 07:00	8.8	8.8	8.8	8.8	8.9	8.9	8.9	8.9	8.9	8.9	9.0	9.0	9.0	9.0
07:00 - 08:00	6.4	6.5	6.5	6.5	6.6	6.6	6.6	6.6	6.6	6.7	6.7	6.7	6.7	6.8
08:00 - 09:00	5.0	5.0	5.0	5.0	5.0	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
09:00 - 10:00	2.5	2.5	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.7	2.7
10:00 - 11:00	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2
11:00 - 12:00	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
12:00 - 13:00	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
13:00 - 14:00	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6
14:00 - 15:00	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
15:00 - 16:00	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
16:00 - 17:00	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0
17:00 - 18:00	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2
18:00 - 19:00	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1
19:00 - 20:00	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
20:00 - 21:00	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
21:00 - 22:00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
22:00 - 23:00	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
23:00 - 24:00	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Winter Westbound

Hour	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
00:00 - 01:00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.6	0.9	0.9
01:00 - 02:00	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
02:00 - 03:00	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
03:00 - 04:00	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
04:00 - 05:00	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
05:00 - 06:00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
06:00 - 07:00	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3
07:00 - 08:00	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
08:00 - 09:00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
09:00 - 10:00	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
10:00 - 11:00	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
11:00 - 12:00	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
12:00 - 13:00	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6
13:00 - 14:00	15.4	15.4	15.4	15.5	15.5	15.5	15.5	15.5	15.5	15.6	15.6	15.6	15.6	15.6
14:00 - 15:00	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.8	15.8	15.8	15.8
15:00 - 16:00	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
16:00 - 17:00	13.8	13.9	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0	14.0	14.0
17:00 - 18:00	8.3	8.4	8.4	8.4	8.4	8.5	8.5	8.5	8.5	8.5	8.6	8.6	8.6	8.6
18:00 - 19:00	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.7	4.7	4.7	4.7
19:00 - 20:00	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
20:00 - 21:00	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
21:00 - 22:00	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
22:00 - 23:00	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
23:00 - 24:00	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

Appendix C
Traffic Forecast by Season, Direction and Hour Interval

Year 1996

Summer - Eastbound	**0-59**	**100-159**	**200-259**	**300-359**	**400-459**
AFR-NAM/CAR/BER	0.143	0.429	0.286	0.857	0.286
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.000	0.000	0.000	0.000
EUR/SCAN-CAR/BER	4.214	4.286	2.786	1.571	2.286
EUR-NAM/EAST	40.643	19.929	16.929	9.929	6.214
EUR-NAM/MIDWEST	9.357	7.071	7.714	5.143	1.929
EUR-NAM/WEST	4.643	4.429	2.214	2.071	3.071
IBE-CAN	0.429	0.429	0.286	0.071	0.143
IBE-CAR	1.143	0.643	0.357	1.000	0.643
IBE-USA/BER	2.571	1.857	1.214	0.929	0.143
SCAN-NAM	3.786	2.286	1.000	1.214	0.714
Total	**66.929**	**41.357**	**32.786**	**22.786**	**15.429**

Summer - Westbound	**0-59**	**100-159**	**200-259**	**300-359**	**400-459**
AFR-NAM/CAR/BER	0.071	0.000	0.000	0.214	0.643
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.000	0.000	0.000	0.071
EUR/SCAN-CAR/BER	0.071	0.143	0.286	0.214	0.286
EUR-NAM/EAST	0.929	1.857	1.929	1.143	1.000
EUR-NAM/MIDWEST	0.071	0.071	0.000	0.000	0.429
EUR-NAM/WEST	0.000	0.000	0.000	0.000	0.000
IBE-CAN	0.000	0.000	0.000	0.000	0.000
IBE-CAR	0.000	0.500	0.000	0.000	0.000
IBE-USA/BER	0.000	0.071	0.071	0.071	0.000
SCAN-NAM	0.071	0.000	0.000	0.071	0.071
Total	**1.214**	**2.643**	**2.286**	**1.714**	**2.500**

Winter - Eastbound	**0-59**	**100-159**	**200-259**	**300-359**	**400-459**
AFR-NAM/CAR/BER	0.300	0.600	0.100	0.200	0.800
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.000	0.000	0.000	0.200
EUR/SCAN-CAR/BER	3.900	5.900	4.000	3.600	1.500
EUR-NAM/EAST	42.100	37.700	13.700	9.400	7.000
EUR-NAM/MIDWEST	8.200	8.300	3.800	5.600	3.400
EUR-NAM/WEST	3.500	2.900	4.400	1.700	2.300
IBE-CAN	0.300	0.600	0.400	0.100	0.100
IBE-CAR	0.800	0.600	0.700	0.300	0.700
IBE-USA/BER	4.400	1.800	0.900	0.200	0.300
SCAN-NAM	4.000	3.200	1.200	0.200	0.000
Total	**67.500**	**61.600**	**29.200**	**21.300**	**16.300**

Winter - Westbound	**0-59**	**100-159**	**200-259**	**300-359**	**400-459**
AFR-NAM/CAR/BER	0.000	0.000	0.000	0.000	0.100
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.100	0.000	0.000	0.100
EUR/SCAN-CAR/BER	0.400	0.200	0.200	0.000	0.000
EUR-NAM/EAST	0.500	0.700	2.200	1.300	1.100
EUR-NAM/MIDWEST	0.200	0.100	0.100	0.000	0.000
EUR-NAM/WEST	0.000	0.000	0.000	0.000	0.000
IBE-CAN	0.000	0.000	0.000	0.000	0.000
IBE-CAR	0.000	0.600	0.100	0.000	0.100
IBE-USA/BER	0.100	0.000	0.000	0.100	0.100
SCAN-NAM	0.100	0.000	0.200	0.100	0.000
Total	**1.300**	**1.700**	**2.800**	**1.500**	**1.500**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.143	0.071	0.143	0.071	0.000	0.000	0.000	0.000
0.429	0.071	0.071	0.000	0.000	0.000	0.143	0.000
1.286	0.071	0.429	0.214	0.214	0.143	0.214	0.286
2.929	2.286	4.071	4.143	2.000	1.714	2.143	2.429
0.286	0.929	0.500	0.143	0.143	0.286	0.571	0.286
2.214	1.000	0.286	0.214	0.214	0.071	0.071	0.000
0.143	0.143	0.071	0.000	0.000	0.143	0.000	0.071
0.286	0.214	0.214	0.000	0.071	0.000	0.000	0.071
0.143	1.143	0.143	0.214	0.000	0.143	0.143	0.571
0.429	0.000	1.929	1.571	0.286	0.286	0.143	0.357
8.286	**5.929**	**7.857**	**6.571**	**2.929**	**2.786**	**3.429**	**4.071**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.214	0.143	0.143	0.000	0.000	0.571	0.071	0.000
0.000	0.071	0.357	0.286	0.429	0.000	0.143	0.071
0.500	0.786	1.429	4.286	8.357	7.214	5.429	3.929
1.429	4.214	6.286	17.857	37.357	43.714	33.500	27.643
0.286	0.500	1.714	4.429	13.214	7.643	11.000	10.571
0.000	0.000	0.643	2.857	4.071	4.500	3.929	2.929
0.071	0.071	0.071	0.071	0.000	0.214	0.143	0.500
0.000	0.000	0.071	0.286	0.643	2.714	2.786	0.929
0.143	0.143	0.357	0.286	1.929	4.071	2.429	2.571
0.143	0.286	1.143	3.857	4.357	4.000	5.143	2.214
2.786	**6.214**	**12.214**	**34.214**	**70.357**	**74.643**	**64.571**	**51.357**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.200	0.000	0.100	0.100	0.000	0.000	0.000	0.100
0.100	0.000	0.100	0.000	0.000	0.000	0.000	0.200
1.900	0.900	0.500	0.500	0.100	0.200	0.100	0.100
4.000	1.900	2.700	2.900	2.300	2.100	1.200	1.800
1.200	0.600	0.600	0.300	0.300	0.200	0.400	0.400
2.200	1.600	0.200	0.200	0.100	0.100	0.200	0.000
0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000
0.600	0.200	0.200	0.000	0.000	0.300	0.000	0.000
0.100	0.100	0.500	0.700	0.000	0.000	0.400	0.200
0.300	0.100	1.200	0.400	1.200	0.200	0.100	0.200
10.600	**5.500**	**6.100**	**5.100**	**4.000**	**3.100**	**2.400**	**3.000**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.600	0.400	0.100	0.000	0.000	0.200	0.000	0.000
0.000	0.000	0.200	0.400	0.400	0.400	0.300	0.100
0.100	0.400	1.000	3.400	5.400	9.100	6.900	6.000
1.200	1.100	2.900	4.200	19.500	37.300	38.200	28.400
0.300	0.200	0.100	0.900	4.400	8.700	6.900	8.900
0.000	0.000	0.200	1.200	2.300	2.500	3.800	3.400
0.000	0.000	0.100	0.000	0.200	0.100	0.100	0.400
0.000	0.200	0.000	0.000	0.000	0.400	2.200	1.300
0.000	0.100	0.000	0.100	0.200	1.500	3.900	2.100
0.000	0.400	0.600	1.000	3.800	3.700	2.500	3.100
2.200	**2.800**	**5.200**	**11.200**	**36.200**	**63.900**	**64.800**	**53.700**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.000	0.000	0.214	0.000	0.000	0.000	0.000	0.071
0.000	0.000	0.000	0.000	0.357	0.000	0.286	1.214
0.214	0.071	0.071	0.000	0.071	0.500	1.571	3.357
5.929	3.857	2.286	1.929	1.143	1.357	1.429	5.571
0.714	0.143	0.214	0.214	0.214	0.286	0.429	1.786
0.000	0.000	0.000	0.000	0.143	0.143	0.214	1.357
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.071	0.000	0.000	0.500	0.357	0.429
0.357	0.429	0.071	0.071	0.071	0.000	0.571	0.857
1.071	0.714	0.429	1.143	0.286	0.143	0.786	1.357
8.286	**5.214**	**3.357**	**3.357**	**2.286**	**2.929**	**5.643**	**16.000**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.000	0.214	0.000	0.071	0.071	0.071	0.071	0.071
0.143	0.714	0.357	0.286	0.357	0.214	0.071	0.000
3.071	1.286	1.286	0.714	0.286	0.286	0.286	0.429
13.571	8.500	9.786	4.214	9.000	4.786	2.214	3.071
7.071	4.000	1.429	1.429	0.786	0.643	0.429	0.714
6.214	1.429	2.286	1.143	0.714	0.857	0.214	0.357
0.143	0.071	0.500	0.000	0.071	0.000	0.000	0.000
0.714	0.786	0.929	0.214	0.143	0.143	0.071	0.000
1.571	0.357	0.571	1.357	0.929	0.929	0.786	0.714
1.071	0.857	0.571	2.786	2.571	0.286	0.786	0.643
33.571	**18.214**	**17.714**	**12.214**	**14.929**	**8.214**	**4.929**	**6.000**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.000
0.000	0.300	0.100	0.000	0.200	0.000	0.300	1.400
0.100	0.000	0.300	0.000	0.000	0.000	0.700	1.900
2.400	5.300	4.200	1.100	1.000	0.200	1.300	0.800
0.000	1.300	0.100	0.700	0.100	0.100	0.000	0.100
0.000	0.000	0.100	0.000	0.000	0.100	0.100	0.900
0.100	0.000	0.000	0.000	0.100	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200
0.400	0.400	0.200	0.200	0.000	0.100	0.100	0.100
0.200	1.300	0.300	0.700	0.000	0.200	0.200	0.600
3.200	**8.600**	**5.300**	**2.700**	**1.500**	**0.700**	**2.700**	**6.000**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.000	0.300	0.000	0.000	0.000	0.000	0.000	0.000
0.100	0.400	0.100	0.400	0.300	0.200	0.000	0.000
5.000	3.000	1.400	0.900	0.500	0.500	0.700	0.100
16.400	10.500	5.800	5.300	2.000	6.800	3.500	2.500
6.300	5.700	2.800	1.600	0.600	0.300	0.500	0.200
3.200	3.100	1.500	2.200	0.500	0.600	0.400	0.100
0.200	0.000	0.000	0.100	0.000	0.000	0.000	0.000
0.500	1.100	1.100	0.600	0.000	0.100	0.000	0.000
2.800	0.800	0.600	0.300	1.100	0.500	0.400	0.200
2.000	0.700	0.500	0.300	3.500	1.100	0.200	0.200
36.500	**25.600**	**13.800**	**11.700**	**8.500**	**10.100**	**5.700**	**3.300**

2100-2159	2200-2259	2300-2359	Total
0.000	0.143	0.643	**3.500**
1.429	0.071	0.143	**4.214**
7.643	6.071	4.857	**42.429**
18.857	35.143	43.786	**236.643**
5.429	12.500	12.714	**69.000**
2.000	4.143	4.857	**33.357**
0.143	0.214	0.071	**2.357**
1.071	1.429	1.286	**9.786**
2.214	2.357	3.571	**19.786**
1.857	4.143	4.714	**30.643**
40.643	**66.214**	**76.643**	**451.714**

2100-2159	2200-2259	2300-2359	Total
0.071	0.357	0.286	**3.357**
0.000	0.000	0.000	**3.571**
0.214	0.214	0.214	**41.214**
2.143	1.857	0.929	**238.929**
0.286	0.357	0.071	**67.143**
0.071	0.000	0.071	**32.286**
0.071	0.000	0.071	**2.071**
0.071	0.000	0.071	**11.071**
0.643	0.357	0.071	**20.429**
0.143	0.357	0.286	**31.714**
3.714	**3.500**	**2.071**	**451.786**

2100-2159	2200-2259	2300-2359	Total
0.000	0.100	0.200	**2.900**
1.400	0.100	0.000	**4.400**
5.300	7.400	6.400	**45.300**
3.300	13.400	32.400	**194.200**
0.600	3.800	10.300	**50.400**
0.900	2.200	3.800	**27.500**
0.000	0.000	0.300	**2.100**
0.200	1.500	2.000	**8.300**
0.700	1.300	2.700	**15.800**
1.400	1.100	3.700	**22.000**
13.800	**30.900**	**61.800**	**372.900**

2100-2159	2200-2259	2300-2359	Total
0.100	0.300	0.400	**2.500**
0.000	0.000	0.000	**3.500**
0.300	0.600	0.400	**46.500**
1.800	2.500	3.500	**199.200**
0.100	0.300	0.400	**49.600**
0.000	0.000	0.000	**25.000**
0.100	0.000	0.000	**1.300**
0.100	0.000	0.000	**8.400**
0.200	0.200	0.100	**15.400**
0.100	0.200	0.000	**24.300**
2.800	**4.100**	**4.800**	**375.700**

Year 2000

Summer - Eastbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	2.585	1.895	1.305	1.035	0.235
EUR/SCAN/IBE-NAM/ALASKA	3.799	2.324	1.090	1.320	0.806
EUR/SCAN-CAR/BER	9.543	7.594	8.954	6.600	3.189
EUR-NAM/EAST	0.959	2.702	6.408	7.532	6.512
EUR-NAM/MIDWEST	4.507	5.110	4.740	3.869	4.272
EUR-NAM/WEST	40.786	20.332	17.884	11.052	7.186
IBE-CAN	0.446	0.478	0.402	0.208	0.261
IBE-CAR	1.189	0.772	0.664	1.361	0.955
IBE-USA/BER	4.723	4.654	2.750	2.701	3.616
SCAN-NAM	0.271	0.791	1.144	1.866	1.158
Total	**68.808**	**46.653**	**45.342**	**37.545**	**28.190**

Summer - Westbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	0.004	0.076	0.075	0.073	0.004
EUR/SCAN/IBE-NAM/ALASKA	0.075	0.004	0.003	0.073	0.076
EUR/SCAN-CAR/BER	0.122	0.130	0.042	0.017	0.488
EUR-NAM/EAST	0.262	0.305	0.218	0.087	0.377
EUR-NAM/MIDWEST	0.151	0.236	0.352	0.241	0.379
EUR-NAM/WEST	0.968	1.903	1.961	1.156	1.046
IBE-CAN	0.005	0.006	0.004	0.002	0.006
IBE-CAR	0.013	0.515	0.010	0.004	0.015
IBE-USA/BER	0.022	0.026	0.018	0.007	0.026
SCAN-NAM	0.106	0.041	0.029	0.226	0.684
Total	**1.727**	**3.241**	**2.713**	**1.885**	**3.098**

Winter - Eastbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	4.404	1.809	0.939	0.300	0.421
EUR/SCAN/IBE-NAM/ALASKA	4.004	3.209	1.240	0.303	0.125
EUR/SCAN-CAR/BER	8.250	8.420	4.312	6.915	4.996
EUR-NAM/EAST	0.253	0.614	2.608	6.704	8.335
EUR-NAM/MIDWEST	3.966	6.060	4.681	5.351	3.625
EUR-NAM/WEST	42.131	37.776	14.022	10.227	8.004
IBE-CAN	0.303	0.606	0.427	0.168	0.183
IBE-CAR	0.812	0.629	0.824	0.618	1.085
IBE-USA/BER	3.518	2.943	4.585	2.174	2.876
SCAN-NAM	0.329	0.670	0.399	0.968	1.732
Total	**67.969**	**62.738**	**34.035**	**33.729**	**31.383**

Winter - Westbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	0.106	0.004	0.004	0.101	0.102
EUR/SCAN/IBE-NAM/ALASKA	0.106	0.004	0.204	0.101	0.002
EUR/SCAN-CAR/BER	0.275	0.153	0.153	0.008	0.030
EUR-NAM/EAST	0.383	0.368	0.268	0.038	0.253
EUR-NAM/MIDWEST	0.500	0.270	0.270	0.010	0.040
EUR-NAM/WEST	0.547	0.733	2.233	1.305	1.119
IBE-CAN	0.004	0.003	0.003	0.000	0.002
IBE-CAR	0.018	0.613	0.113	0.002	0.107
IBE-USA/BER	0.027	0.019	0.019	0.003	0.011
SCAN-NAM	0.044	0.031	0.031	0.004	0.118
Total	**2.009**	**2.197**	**3.297**	**1.571**	**1.784**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.215	1.189	0.181	0.237	0.012	0.151	0.155	0.580
0.499	0.046	1.967	1.594	0.297	0.294	0.154	0.366
1.264	1.558	1.025	0.455	0.303	0.395	0.732	0.404
5.485	3.326	2.783	1.613	0.828	0.567	0.971	0.610
2.828	1.065	1.256	0.706	0.467	0.316	0.467	0.472
3.683	2.771	4.476	4.383	2.124	1.799	2.266	2.520
0.235	0.202	0.121	0.029	0.015	0.153	0.015	0.083
0.528	0.370	0.344	0.077	0.111	0.027	0.040	0.101
2.637	1.272	0.512	0.349	0.283	0.119	0.141	0.051
0.820	0.508	0.506	0.288	0.111	0.076	0.111	0.082
18.194	**12.307**	**13.170**	**9.732**	**4.551**	**3.896**	**5.051**	**5.267**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.150	0.147	0.359	0.291	1.938	4.085	2.473	2.657
0.150	0.290	1.145	3.862	4.366	4.013	5.186	2.299
0.387	0.559	1.740	4.496	13.341	7.828	11.602	11.739
0.523	0.377	0.488	0.635	1.083	0.959	3.253	6.106
0.660	0.879	1.468	4.392	8.557	7.507	6.377	5.769
1.507	4.260	6.305	17.909	37.455	43.857	33.964	28.543
0.081	0.077	0.074	0.078	0.012	0.232	0.199	0.610
0.025	0.015	0.078	0.302	0.674	2.760	2.935	1.218
0.044	0.026	0.654	2.886	4.126	4.580	4.188	3.433
0.284	0.184	0.160	0.047	0.088	0.700	0.488	0.809
3.811	**6.812**	**12.471**	**34.898**	**71.639**	**76.522**	**70.665**	**63.182**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.182	0.150	0.537	0.729	0.014	0.012	0.407	0.207
0.384	0.152	1.238	0.429	1.215	0.212	0.107	0.207
2.276	1.262	1.086	0.676	0.489	0.353	0.490	0.493
5.584	3.375	2.581	1.918	0.967	0.782	0.460	0.676
3.333	1.782	1.148	1.001	0.353	0.405	0.220	0.224
4.677	2.316	3.006	3.137	2.419	2.197	1.257	1.859
0.056	0.134	0.025	0.020	0.010	0.008	0.005	0.005
0.860	0.360	0.317	0.091	0.046	0.337	0.022	0.022
2.588	1.839	0.376	0.336	0.168	0.155	0.233	0.034
0.829	0.387	0.384	0.320	0.111	0.090	0.053	0.155
20.768	**11.757**	**10.699**	**8.655**	**5.792**	**4.551**	**3.253**	**3.882**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.003	0.108	0.005	0.103	0.203	1.508	3.911	2.138
0.003	0.409	0.605	1.003	3.804	3.708	2.511	3.139
0.338	0.310	0.168	0.938	4.445	8.805	7.043	9.403
0.191	0.559	0.544	0.591	0.630	0.936	1.027	2.664
0.150	0.546	1.090	3.450	5.460	9.240	7.090	6.670
1.224	1.169	2.942	4.224	19.528	37.366	38.290	28.716
0.002	0.006	0.104	0.002	0.202	0.105	0.107	0.426
0.009	0.227	0.016	0.009	0.011	0.425	2.234	1.421
0.014	0.039	0.224	1.214	2.316	2.538	3.851	3.581
0.622	0.464	0.139	0.022	0.026	0.261	0.083	0.294
2.555	**3.836**	**5.839**	**11.555**	**36.626**	**64.893**	**66.148**	**58.453**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.361	0.435	0.076	0.078	0.083	0.005	0.577	0.860
1.075	0.721	0.433	1.150	0.298	0.148	0.791	1.360
0.765	0.236	0.273	0.307	0.377	0.353	0.501	1.819
0.262	0.479	0.305	0.479	1.199	0.349	0.660	1.389
0.294	0.218	0.165	0.146	0.328	0.606	1.686	3.410
5.968	3.929	2.331	2.000	1.268	1.409	1.484	5.597
0.005	0.009	0.006	0.009	0.015	0.006	0.007	0.003
0.013	0.023	0.086	0.023	0.040	0.517	0.375	0.437
0.022	0.040	0.025	0.040	0.213	0.172	0.246	1.372
0.035	0.064	0.255	0.064	0.113	0.047	0.050	0.095
8.798	**6.154**	**3.955**	**4.297**	**3.936**	**3.612**	**6.377**	**16.342**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
1.670	0.453	0.653	1.404	0.962	0.951	0.799	0.729
1.169	0.952	0.652	2.832	2.604	0.308	0.799	0.658
8.413	5.313	2.545	2.061	1.241	0.955	0.614	0.917
7.075	7.498	6.130	3.556	2.712	1.828	1.031	1.046
5.186	3.355	3.047	1.712	1.004	0.778	0.578	0.748
14.606	9.512	10.647	4.702	9.351	5.026	2.357	3.228
0.269	0.195	0.605	0.059	0.114	0.029	0.017	0.019
1.046	1.111	1.205	0.371	0.256	0.220	0.117	0.050
6.794	1.995	2.768	1.416	0.911	0.992	0.294	0.445
0.929	1.123	0.774	0.510	0.387	0.288	0.200	0.212
47.156	**31.508**	**29.027**	**18.622**	**19.542**	**11.375**	**6.808**	**8.051**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.409	0.403	0.207	0.206	0.007	0.113	0.105	0.104
0.209	1.304	0.307	0.706	0.008	0.213	0.205	0.604
0.113	1.345	0.193	0.783	0.198	0.266	0.060	0.153
0.575	0.530	0.573	0.422	0.699	0.844	0.607	1.668
0.250	0.060	0.423	0.110	0.130	0.220	0.780	1.970
2.471	5.328	4.258	1.152	1.062	0.304	1.338	0.833
0.106	0.002	0.005	0.004	0.105	0.009	0.003	0.003
0.027	0.011	0.022	0.020	0.024	0.040	0.015	0.213
0.041	0.016	0.133	0.030	0.035	0.160	0.122	0.919
0.066	0.026	0.054	0.048	0.157	0.097	0.035	0.031
4.267	**9.027**	**6.176**	**3.482**	**2.424**	**2.264**	**3.269**	**6.498**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
2.888	0.891	0.687	0.379	1.148	0.526	0.415	0.213
2.090	0.793	0.589	0.381	3.549	1.127	0.215	0.213
7.457	6.893	3.941	2.641	1.228	0.645	0.695	0.365
6.001	6.484	5.917	5.707	3.502	1.960	0.995	0.842
6.542	4.590	2.920	2.287	1.337	0.960	0.960	0.320
17.128	11.251	6.518	5.955	2.395	7.017	3.623	2.604
0.260	0.062	0.059	0.154	0.033	0.018	0.010	0.009
0.779	1.388	1.376	0.851	0.152	0.183	0.047	0.040
3.618	3.531	1.912	2.576	0.727	0.725	0.470	0.160
0.676	0.997	0.667	0.608	0.367	0.202	0.114	0.097
47.440	**36.881**	**24.584**	**21.539**	**14.437**	**13.364**	**7.545**	**4.861**

2100-2159	2200-2259	2300-2359	Total
2.217	2.360	3.578	**20.405**
1.860	4.145	4.720	**31.255**
5.462	12.534	12.799	**77.443**
1.603	0.246	0.579	**47.846**
7.696	6.125	4.990	**55.738**
18.883	35.169	43.851	**243.152**
0.146	0.217	0.079	**3.151**
1.080	1.437	1.307	**11.876**
2.015	4.157	4.894	**37.003**
0.023	0.166	0.701	**9.346**
40.985	**66.556**	**77.497**	**537.214**

2100-2159	2200-2259	2300-2359	Total
0.653	0.366	0.075	**21.048**
0.153	0.366	0.289	**32.326**
0.429	0.484	0.122	**75.585**
0.741	0.654	0.262	**47.204**
0.440	0.414	0.294	**54.524**
2.253	1.955	0.968	**245.438**
0.085	0.012	0.076	**2.865**
0.107	0.031	0.084	**13.161**
0.133	0.055	0.093	**35.932**
0.171	0.445	0.321	**9.203**
5.167	**4.782**	**2.584**	**537.286**

2100-2159	2200-2259	2300-2359	Total
0.703	1.301	2.702	**16.371**
1.403	1.101	3.702	**22.587**
0.638	3.815	10.330	**57.912**
1.592	0.177	0.153	**42.696**
5.350	7.420	6.440	**55.306**
3.324	13.409	32.419	**198.925**
0.002	0.001	0.302	**2.490**
0.209	1.504	2.007	**10.114**
0.914	2.205	3.811	**30.210**
0.022	0.109	0.218	**7.290**
14.156	**31.042**	**62.084**	**443.900**

2100-2159	2200-2259	2300-2359	Total
0.214	0.207	0.108	**15.971**
0.114	0.207	0.008	**24.887**
0.280	0.395	0.505	**57.112**
0.918	0.482	0.536	**41.796**
0.540	0.726	0.540	**56.506**
1.913	2.559	3.566	**203.925**
0.109	0.005	0.005	**1.690**
0.144	0.023	0.025	**10.214**
0.065	0.034	0.038	**27.710**
0.205	0.355	0.461	**6.890**
4.503	**4.994**	**5.793**	**446.700**

Year 2005

Summer - Eastbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	4.735	4.690	2.833	2.799	3.701
EUR/SCAN/IBE-NAM/ALASKA	0.283	0.825	1.225	1.961	1.241
EUR/SCAN-CAR/BER	4.707	5.674	6.076	5.432	5.636
EUR-NAM/EAST	4.715	4.906	7.211	8.483	7.052
EUR-NAM/MIDWEST	9.851	8.464	11.017	9.013	5.293
EUR-NAM/WEST	1.105	3.113	7.381	8.671	7.506
IBE-CAN	0.459	0.516	0.492	0.313	0.353
IBE-CAR	1.233	0.896	0.958	1.704	1.254
IBE-USA/BER	40.856	20.529	18.351	11.598	7.662
SCAN-NAM	2.698	2.213	2.058	1.917	1.004
Total	**70.643**	**51.824**	**57.603**	**51.892**	**40.702**

Summer - Westbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	0.025	0.030	0.021	0.008	0.029
EUR/SCAN/IBE-NAM/ALASKA	0.110	0.045	0.032	0.227	0.688
EUR/SCAN-CAR/BER	0.206	0.309	0.398	0.259	0.442
EUR-NAM/EAST	0.325	0.337	0.211	0.156	0.367
EUR-NAM/MIDWEST	0.206	0.243	0.112	0.045	0.586
EUR-NAM/WEST	0.301	0.358	0.251	0.100	0.423
IBE-CAN	0.008	0.010	0.007	0.003	0.010
IBE-CAR	0.025	0.531	0.020	0.008	0.029
IBE-USA/BER	0.987	1.928	1.977	1.162	1.068
SCAN-NAM	0.034	0.117	0.100	0.083	0.040
Total	**2.227**	**3.908**	**3.130**	**2.052**	**3.682**

Winter - Eastbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	3.521	2.952	4.620	2.263	2.982
EUR/SCAN/IBE-NAM/ALASKA	0.332	0.679	0.434	1.058	1.841
EUR/SCAN-CAR/BER	4.016	6.195	5.261	6.812	5.387
EUR-NAM/EAST	4.223	3.793	3.758	6.651	7.780
EUR-NAM/MIDWEST	8.310	8.582	5.007	8.669	7.111
EUR-NAM/WEST	0.282	0.692	2.945	7.552	9.359
IBE-CAN	0.304	0.611	0.446	0.217	0.241
IBE-CAR	0.823	0.657	0.945	0.923	1.454
IBE-USA/BER	42.145	37.812	14.177	10.619	8.476
SCAN-NAM	4.427	1.870	1.202	0.964	1.222
Total	**68.383**	**63.841**	**38.794**	**45.728**	**45.852**

Winter - Westbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	0.032	0.023	0.023	0.003	0.013
EUR/SCAN/IBE-NAM/ALASKA	0.049	0.034	0.035	0.005	0.120
EUR/SCAN-CAR/BER	0.584	0.329	0.336	0.018	0.074
EUR-NAM/EAST	0.471	0.260	0.488	0.137	0.149
EUR-NAM/MIDWEST	0.376	0.223	0.231	0.018	0.070
EUR-NAM/WEST	0.432	0.402	0.306	0.043	0.273
IBE-CAN	0.007	0.005	0.005	0.001	0.003
IBE-CAR	0.036	0.625	0.126	0.004	0.114
IBE-USA/BER	0.570	0.749	2.251	1.307	1.128
SCAN-NAM	0.144	0.031	0.034	0.104	0.118
Total	**2.700**	**2.680**	**3.834**	**1.640**	**2.060**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
2.703	1.315	0.548	0.371	0.294	0.126	0.151	0.059
0.884	0.549	0.541	0.308	0.121	0.083	0.121	0.089
3.882	1.746	1.828	1.052	0.640	0.434	0.640	0.599
5.330	3.169	4.590	3.176	1.089	0.835	0.946	0.949
2.892	2.611	1.908	0.988	0.570	0.578	0.998	0.600
6.253	3.823	3.200	1.865	0.954	0.653	1.097	0.703
0.306	0.248	0.159	0.053	0.027	0.161	0.027	0.091
0.760	0.520	0.470	0.153	0.149	0.053	0.078	0.129
4.051	3.009	4.676	4.504	2.184	1.840	2.327	2.564
0.809	1.573	0.504	0.432	0.109	0.217	0.252	0.652
27.870	**18.563**	**18.425**	**12.901**	**6.136**	**4.980**	**6.636**	**6.435**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.050	0.029	0.655	2.891	4.135	4.593	4.228	3.513
0.291	0.187	0.162	0.051	0.096	0.712	0.527	0.886
0.765	0.939	1.491	4.465	8.693	7.705	7.013	7.045
0.635	0.566	1.247	4.195	4.991	4.922	8.101	8.144
0.550	0.652	1.774	4.608	13.551	8.134	12.584	13.708
0.600	0.420	0.504	0.688	1.182	1.104	3.716	7.036
0.088	0.081	0.075	0.083	0.021	0.245	0.242	0.695
0.048	0.028	0.083	0.318	0.704	2.804	3.075	1.498
1.544	4.281	6.313	17.935	37.502	43.927	34.186	28.989
0.210	0.181	0.372	0.332	2.015	4.197	2.831	3.376
4.781	**7.365**	**12.674**	**35.565**	**72.890**	**78.342**	**76.504**	**74.890**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
2.661	1.884	0.409	0.361	0.182	0.166	0.239	0.040
0.902	0.433	0.418	0.346	0.124	0.101	0.059	0.161
4.533	2.529	1.702	1.427	0.571	0.584	0.328	0.334
5.602	3.399	3.646	2.282	2.163	0.992	0.573	0.682
3.717	2.159	1.751	1.188	0.752	0.569	0.619	0.624
6.282	3.809	2.902	2.165	1.093	0.887	0.523	0.739
0.096	0.159	0.044	0.034	0.017	0.014	0.008	0.008
1.111	0.516	0.433	0.180	0.091	0.375	0.044	0.045
4.999	2.517	3.155	3.251	2.478	2.245	1.285	1.888
0.728	0.490	0.789	0.922	0.114	0.093	0.456	0.257
30.630	**17.895**	**15.250**	**12.157**	**7.585**	**6.024**	**4.134**	**4.778**

500-559	600-659	700-759	800-859	900-959	1000-1059	1100-1159	1200-1259
0.016	0.047	0.228	1.216	2.319	2.545	3.861	3.615
0.625	0.471	0.144	0.025	0.029	0.268	0.093	0.328
0.192	0.662	1.157	3.492	5.510	9.351	7.250	7.233
0.186	0.914	0.898	1.186	4.023	4.192	3.205	5.588
0.388	0.449	0.248	0.988	4.506	8.939	7.234	10.079
0.216	0.626	0.583	0.616	0.659	1.000	1.120	2.991
0.003	0.010	0.106	0.003	0.204	0.109	0.113	0.445
0.018	0.251	0.030	0.018	0.021	0.449	2.268	1.539
1.235	1.200	2.961	4.235	19.542	37.396	38.333	28.867
0.022	0.161	0.036	0.122	0.226	1.559	3.983	2.394
2.900	**4.790**	**6.391**	**11.900**	**37.040**	**65.807**	**67.460**	**63.081**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.025	0.046	0.029	0.046	0.224	0.177	0.250	1.374
0.038	0.070	0.259	0.070	0.123	0.051	0.055	0.097
0.349	0.316	0.228	0.246	0.501	0.679	1.758	3.447
1.325	1.171	0.724	1.608	1.089	0.481	1.124	1.526
0.849	0.387	0.372	0.461	0.644	0.465	0.613	1.876
0.301	0.551	0.351	0.552	1.325	0.402	0.713	1.415
0.008	0.015	0.010	0.015	0.027	0.011	0.012	0.006
0.025	0.045	0.100	0.045	0.078	0.533	0.391	0.445
5.987	3.963	2.353	2.035	1.329	1.435	1.510	5.610
0.392	0.491	0.112	0.135	0.181	0.046	0.618	0.880
9.299	**7.056**	**4.539**	**5.214**	**5.521**	**4.279**	**7.044**	**16.675**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
6.884	2.083	2.844	1.459	0.942	1.013	0.307	0.458
1.017	1.209	0.847	0.551	0.417	0.308	0.212	0.225
6.631	4.764	4.263	2.393	1.495	1.116	0.778	0.966
7.790	7.407	6.223	5.955	4.853	1.858	1.715	1.657
10.644	7.487	4.422	3.114	1.999	1.477	0.923	1.253
8.129	8.525	7.016	4.053	3.069	2.074	1.176	1.205
0.366	0.289	0.687	0.105	0.147	0.052	0.031	0.034
1.364	1.420	1.472	0.521	0.364	0.294	0.161	0.098
15.110	10.004	11.072	4.940	9.523	5.145	2.427	3.304
2.484	1.247	1.338	1.788	1.239	1.142	0.912	0.852
60.418	**44.436**	**40.184**	**24.878**	**24.046**	**14.480**	**8.643**	**10.052**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
0.048	0.019	0.139	0.035	0.042	0.171	0.126	0.922
0.074	0.029	0.060	0.054	0.164	0.108	0.039	0.034
0.376	0.110	0.524	0.203	0.238	0.405	0.847	2.021
0.756	1.522	0.745	1.108	0.475	1.016	0.497	0.823
0.264	1.406	0.314	0.894	0.327	0.487	0.141	0.213
0.648	0.559	0.631	0.476	0.761	0.951	0.646	1.698
0.110	0.004	0.008	0.007	0.109	0.015	0.005	0.004
0.054	0.021	0.044	0.039	0.046	0.079	0.029	0.223
2.505	5.342	4.285	1.177	1.090	0.354	1.356	0.847
0.466	0.426	0.253	0.248	0.056	0.197	0.135	0.127
5.301	**9.440**	**7.004**	**4.241**	**3.308**	**3.781**	**3.821**	**6.912**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
3.696	3.611	1.989	2.646	0.770	0.748	0.484	0.171
0.756	1.079	0.745	0.680	0.411	0.226	0.127	0.108
7.845	5.927	4.198	3.457	2.050	1.348	1.179	0.505
7.755	6.604	6.144	5.468	6.647	2.815	1.165	1.017
9.022	8.499	5.475	4.046	2.084	1.112	0.958	0.587
6.758	7.261	6.659	6.387	3.916	2.186	1.122	0.949
0.303	0.106	0.101	0.193	0.056	0.031	0.017	0.015
1.052	1.668	1.643	1.096	0.301	0.265	0.093	0.079
17.478	11.609	6.860	6.269	2.586	7.121	3.681	2.653
3.480	1.498	1.268	0.911	1.472	0.703	0.514	0.297
58.146	**47.863**	**35.083**	**31.152**	**20.292**	**16.553**	**9.340**	**6.380**

2100-2159	2200-2259	2300-2359	Total
2.016	4.160	4.899	**37.572**
0.025	0.168	0.707	**9.899**
7.725	6.161	5.081	**64.837**
1.994	4.312	5.137	**72.942**
5.507	12.590	12.939	**91.487**
1.624	0.272	0.645	**54.478**
0.148	0.220	0.085	**3.761**
1.086	1.445	1.327	**13.876**
18.893	35.182	43.882	**246.330**
2.233	2.380	3.629	**25.533**
41.254	**66.890**	**78.331**	**620.714**

2100-2159	2200-2259	2300-2359	Total
0.143	0.063	0.097	**36.501**
0.180	0.453	0.324	**9.756**
0.595	0.543	0.349	**63.622**
0.861	0.959	0.539	**74.013**
0.668	0.683	0.206	**89.630**
0.854	0.748	0.301	**53.835**
0.095	0.021	0.080	**3.476**
0.141	0.060	0.096	**15.161**
2.307	2.000	0.987	**248.616**
0.740	0.439	0.106	**26.176**
6.585	**5.968**	**3.085**	**620.786**

2100-2159	2200-2259	2300-2359	Total
0.916	2.206	3.813	**30.717**
0.025	0.110	0.220	**7.805**
5.392	7.437	6.474	**63.705**
1.585	1.174	3.848	**59.093**
0.688	3.835	10.370	**67.996**
1.616	0.186	0.173	**47.576**
0.003	0.001	0.303	**2.767**
0.218	1.507	2.014	**11.873**
3.335	13.414	32.428	**201.177**
0.722	1.309	2.718	**20.189**
14.500	**31.180**	**62.360**	**512.900**

2100-2159	2200-2259	2300-2359	Total
0.077	0.040	0.045	**28.217**
0.217	0.361	0.468	**7.405**
0.733	0.827	0.649	**64.905**
0.955	0.646	0.483	**61.393**
0.512	0.516	0.636	**67.196**
1.031	0.541	0.599	**46.676**
0.116	0.008	0.009	**1.967**
0.184	0.044	0.048	**11.973**
1.965	2.587	3.595	**206.177**
0.302	0.253	0.158	**19.789**
6.091	**5.823**	**6.691**	**515.700**

Year 2010

Summer - Eastbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	40.865	20.555	18.415	11.672	7.727
EUR/SCAN/IBE-NAM/ALASKA	2.706	2.237	2.115	1.983	1.061
EUR/SCAN-CAR/BER	10.037	8.986	12.254	10.461	6.559
EUR-NAM/EAST	1.053	2.994	6.369	7.979	6.503
EUR-NAM/MIDWEST	4.999	6.498	8.031	7.719	7.635
EUR-NAM/WEST	4.847	5.275	8.089	9.509	7.950
IBE-CAN	0.469	0.542	0.555	0.388	0.418
IBE-CAR	1.265	0.988	1.176	1.960	1.478
IBE-USA/BER	1.155	3.256	7.720	9.067	7.852
SCAN-NAM	4.818	4.921	3.383	3.442	4.263
Total	**72.215**	**56.254**	**68.106**	**64.180**	**51.447**

Summer - Westbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	0.989	1.932	1.979	1.163	1.071
EUR/SCAN/IBE-NAM/ALASKA	0.037	0.120	0.102	0.084	0.043
EUR/SCAN-CAR/BER	0.257	0.310	0.154	0.062	0.645
EUR-NAM/EAST	0.320	0.325	0.207	0.297	0.933
EUR-NAM/MIDWEST	0.286	0.415	0.464	0.286	0.536
EUR-NAM/WEST	0.361	0.385	0.241	0.168	0.409
IBE-CAN	0.011	0.014	0.009	0.004	0.013
IBE-CAR	0.033	0.543	0.028	0.011	0.039
IBE-USA/BER	0.315	0.377	0.263	0.105	0.439
SCAN-NAM	0.048	0.060	0.040	0.016	0.056
Total	**2.656**	**4.480**	**3.488**	**2.195**	**4.183**

Winter - Eastbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	42.147	37.818	14.202	10.682	8.552
EUR/SCAN/IBE-NAM/ALASKA	4.429	1.876	1.229	1.031	1.303
EUR/SCAN-CAR/BER	8.356	8.708	5.553	10.039	8.760
EUR-NAM/EAST	0.511	1.173	2.566	6.408	8.277
EUR-NAM/MIDWEST	4.070	6.342	5.895	8.405	7.303
EUR-NAM/WEST	4.249	3.864	4.063	7.419	8.704
IBE-CAN	0.305	0.614	0.458	0.247	0.278
IBE-CAR	0.830	0.678	1.035	1.150	1.727
IBE-USA/BER	0.291	0.717	3.053	7.824	9.686
SCAN-NAM	3.537	2.995	4.808	2.737	3.553
Total	**68.725**	**64.785**	**42.863**	**55.943**	**58.143**

Winter - Westbound	0-59	100-159	200-259	300-359	400-459
AFR-NAM/CAR/BER	0.573	0.751	2.253	1.307	1.129
EUR/SCAN/IBE-NAM/ALASKA	0.148	0.033	0.037	0.105	0.119
EUR/SCAN-CAR/BER	0.449	0.279	0.294	0.026	0.102
EUR-NAM/EAST	0.334	0.251	0.282	0.036	0.243
EUR-NAM/MIDWEST	0.669	0.393	0.409	0.028	0.110
EUR-NAM/WEST	0.512	0.291	0.524	0.142	0.166
IBE-CAN	0.008	0.006	0.006	0.001	0.003
IBE-CAR	0.048	0.634	0.137	0.005	0.120
IBE-USA/BER	0.446	0.413	0.318	0.045	0.279
SCAN-NAM	0.057	0.042	0.045	0.006	0.024
Total	**3.244**	**3.094**	**4.306**	**1.699**	**2.296**

500-559	**600-659**	**700-759**	**800-859**	**900-959**	**1000-1059**	**1100-1159**	**1200-1259**
4.101	3.042	4.704	4.520	2.192	1.846	2.335	2.570
0.853	1.602	0.529	0.446	0.116	0.222	0.259	0.657
3.868	3.250	2.447	1.308	0.723	0.687	1.162	0.718
4.943	3.208	2.780	1.638	0.758	0.538	0.800	0.579
5.425	2.757	2.679	1.557	0.882	0.607	0.898	0.785
6.022	3.622	4.972	3.403	1.197	0.913	1.061	1.032
0.356	0.281	0.187	0.069	0.035	0.167	0.035	0.097
0.932	0.633	0.565	0.210	0.176	0.072	0.106	0.149
6.520	3.998	3.348	1.952	0.996	0.683	1.142	0.735
3.137	1.599	0.787	0.513	0.362	0.175	0.224	0.111
36.157	**23.993**	**22.998**	**15.616**	**7.437**	**5.909**	**8.022**	**7.435**

500-559	**600-659**	**700-759**	**800-859**	**900-959**	**1000-1059**	**1100-1159**	**1200-1259**
1.548	4.284	6.314	17.938	37.509	43.936	34.216	29.050
0.214	0.184	0.372	0.335	2.020	4.205	2.858	3.431
0.643	0.702	1.790	4.676	13.678	8.311	13.174	14.905
0.676	0.398	0.232	0.331	0.621	1.447	2.978	5.859
0.912	1.019	1.517	4.571	8.893	7.985	7.945	8.935
0.700	0.602	1.259	4.243	5.081	5.047	8.519	8.992
0.093	0.084	0.076	0.086	0.028	0.254	0.272	0.757
0.065	0.037	0.086	0.330	0.726	2.835	3.179	1.709
0.626	0.434	0.509	0.706	1.217	1.152	3.878	7.363
0.092	0.052	0.663	2.921	4.191	4.671	4.490	4.044
5.568	**7.794**	**12.817**	**36.137**	**73.963**	**79.844**	**81.510**	**85.045**

500-559	**600-659**	**700-759**	**800-859**	**900-959**	**1000-1059**	**1100-1159**	**1200-1259**
5.051	2.550	3.179	3.270	2.488	2.253	1.290	1.893
0.783	0.525	0.815	0.942	0.124	0.102	0.461	0.262
4.845	2.870	2.283	1.591	0.965	0.743	0.722	0.727
5.307	3.206	2.494	1.921	0.958	0.780	0.461	0.563
5.845	3.355	2.320	1.897	0.819	0.787	0.447	0.453
6.234	3.797	3.944	2.508	2.283	1.089	0.631	0.739
0.121	0.175	0.055	0.043	0.022	0.018	0.011	0.011
1.298	0.634	0.521	0.247	0.127	0.403	0.061	0.062
6.506	3.950	3.008	2.245	1.136	0.921	0.543	0.759
3.051	2.130	0.593	0.501	0.256	0.226	0.275	0.076
39.040	**23.191**	**19.213**	**15.165**	**9.178**	**7.322**	**4.901**	**5.545**

500-559	**600-659**	**700-759**	**800-859**	**900-959**	**1000-1059**	**1100-1159**	**1200-1259**
1.237	1.205	2.963	4.237	19.544	37.401	38.340	28.892
0.024	0.166	0.039	0.124	0.229	1.564	3.991	2.420
0.428	0.552	0.312	1.028	4.552	9.042	7.385	10.602
0.779	0.873	0.391	0.179	0.209	0.670	0.681	2.370
0.238	0.782	1.231	3.538	5.564	9.471	7.425	7.841
0.208	0.971	0.933	1.208	4.049	4.249	3.290	5.881
0.004	0.012	0.107	0.004	0.205	0.111	0.116	0.456
0.024	0.268	0.041	0.024	0.029	0.466	2.293	1.626
0.224	0.646	0.596	0.624	0.668	1.021	1.150	3.095
0.030	0.082	0.250	1.230	2.335	2.580	3.913	3.796
3.195	**5.558**	**6.864**	**12.195**	**37.383**	**66.574**	**68.582**	**66.979**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
5.989	3.967	2.356	2.040	1.337	1.438	1.513	5.612
0.394	0.495	0.114	0.139	0.188	0.049	0.621	0.882
0.898	0.471	0.430	0.554	0.804	0.531	0.681	1.909
0.241	0.420	0.504	0.455	0.788	0.324	0.334	0.237
0.426	0.449	0.321	0.392	0.753	0.783	1.865	3.500
1.360	1.231	0.766	1.673	1.202	0.527	1.172	1.550
0.011	0.020	0.013	0.020	0.035	0.015	0.015	0.007
0.033	0.059	0.110	0.061	0.107	0.544	0.403	0.451
0.315	0.574	0.368	0.578	1.369	0.420	0.732	1.424
0.047	0.084	0.056	0.087	0.295	0.206	0.280	1.389
9.713	**7.770**	**5.039**	**6.000**	**6.878**	**4.836**	**7.616**	**16.961**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
15.179	10.071	11.130	4.973	9.546	5.161	2.437	3.314
2.545	1.307	1.391	1.817	1.259	1.156	0.920	0.861
11.978	8.786	5.563	3.752	2.454	1.789	1.108	1.447
6.564	6.609	5.589	3.206	2.308	1.604	0.983	1.030
8.739	6.816	6.065	3.402	2.213	1.608	1.071	1.272
8.736	8.328	7.031	6.407	5.176	2.079	1.847	1.794
0.434	0.356	0.745	0.138	0.171	0.068	0.040	0.044
1.600	1.650	1.674	0.634	0.444	0.350	0.194	0.132
8.494	8.881	7.328	4.227	3.194	2.159	1.227	1.258
7.477	2.661	3.351	1.742	1.144	1.152	0.389	0.544
71.746	**55.464**	**49.867**	**30.298**	**27.908**	**17.126**	**10.216**	**11.697**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
2.510	5.344	4.290	1.180	1.095	0.362	1.359	0.849
0.472	0.429	0.258	0.252	0.061	0.205	0.138	0.129
0.387	1.453	0.409	0.973	0.422	0.660	0.204	0.261
0.555	0.215	0.431	0.363	0.534	0.782	0.286	0.219
0.520	0.166	0.634	0.295	0.348	0.606	0.921	2.076
0.825	1.549	0.798	1.152	0.529	1.112	0.532	0.850
0.113	0.005	0.010	0.009	0.111	0.019	0.007	0.005
0.074	0.029	0.059	0.052	0.062	0.107	0.039	0.231
0.673	0.569	0.650	0.491	0.780	0.985	0.658	1.707
0.091	0.036	0.172	0.063	0.075	0.231	0.148	0.938
6.221	**9.794**	**7.712**	**4.830**	**4.016**	**5.067**	**4.292**	**7.265**

1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859	1900-1959	2000-2059
17.535	11.667	6.916	6.320	2.618	7.139	3.691	2.662
3.541	1.560	1.327	0.966	1.505	0.721	0.524	0.305
10.258	9.752	6.680	5.155	2.763	1.484	1.164	0.762
5.581	5.973	5.446	5.010	3.064	1.679	0.932	0.788
9.282	7.384	5.598	4.746	2.840	1.781	1.418	0.708
8.447	7.306	6.819	6.089	7.028	3.023	1.281	1.115
0.331	0.134	0.128	0.218	0.071	0.039	0.022	0.019
1.257	1.876	1.842	1.280	0.413	0.326	0.127	0.107
7.003	7.510	6.898	6.607	4.051	2.260	1.163	0.984
4.124	4.045	2.406	3.030	1.005	0.877	0.555	0.231
67.360	**57.206**	**44.060**	**39.420**	**25.359**	**19.329**	**10.876**	**7.680**

2100-2159	2200-2259	2300-2359	Total
18.895	35.183	43.886	**246.762**
2.235	2.382	3.632	**25.918**
5.533	12.624	13.016	**99.910**
0.130	0.308	1.029	**44.915**
7.765	6.214	5.203	**78.142**
2.012	4.336	5.192	**78.914**
0.149	0.222	0.089	**4.193**
1.091	1.451	1.340	**15.364**
1.631	0.281	0.666	**56.782**
2.028	4.175	4.934	**41.315**
41.468	**67.175**	**78.989**	**692.2143**

2100-2159	2200-2259	2300-2359	Total
2.315	2.006	0.989	**249.048**
0.747	0.445	0.108	**26.561**
0.811	0.801	0.257	**98.053**
0.776	0.943	0.534	**44.772**
0.821	0.729	0.428	**76.927**
0.963	1.043	0.575	**79.985**
0.103	0.027	0.082	**3.908**
0.166	0.081	0.105	**16.650**
0.893	0.780	0.315	**56.139**
0.207	0.115	0.119	**40.243**
7.800	**6.969**	**3.514**	**692.286**

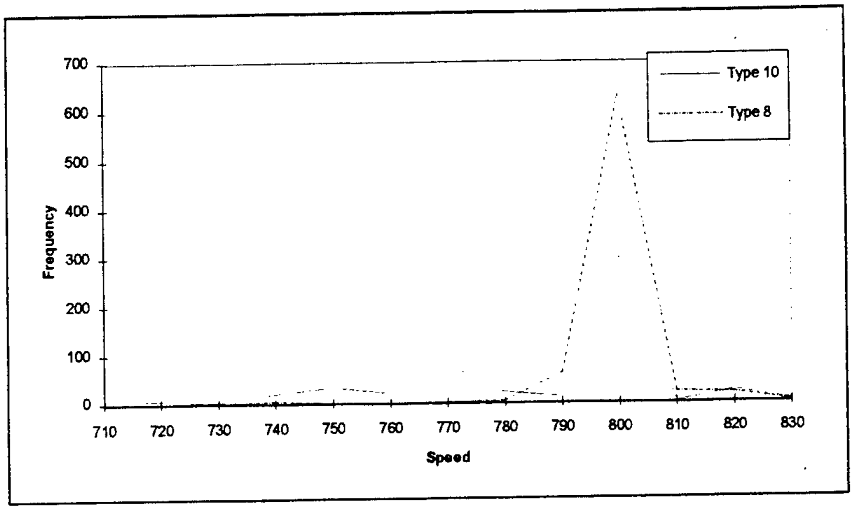
2100-2159	2200-2259	2300-2359	Total
3.337	13.415	32.429	**201.543**
0.724	1.310	2.719	**20.579**
0.728	3.851	10.402	**75.911**
0.179	0.172	0.343	**38.703**
5.438	7.455	6.510	**72.906**
1.608	1.183	3.866	**63.528**
0.004	0.002	0.303	**2.944**
0.224	1.510	2.020	**13.183**
1.624	0.190	0.179	**49.145**
0.930	2.212	3.824	**33.456**
14.795	**31.298**	**62.596**	**571.900**

2100-2159	2200-2259	2300-2359	Total
1.974	2.591	3.600	**206.543**
0.311	0.258	0.163	**20.179**
0.695	0.611	0.739	**75.111**
0.929	0.733	0.870	**38.303**
0.945	0.937	0.769	**74.106**
1.057	0.699	0.541	**65.828**
0.120	0.010	0.011	**2.144**
0.214	0.060	0.065	**13.283**
1.067	0.560	0.620	**48.245**
0.140	0.073	0.080	**30.956**
7.450	**6.531**	**7.459**	**574.700**

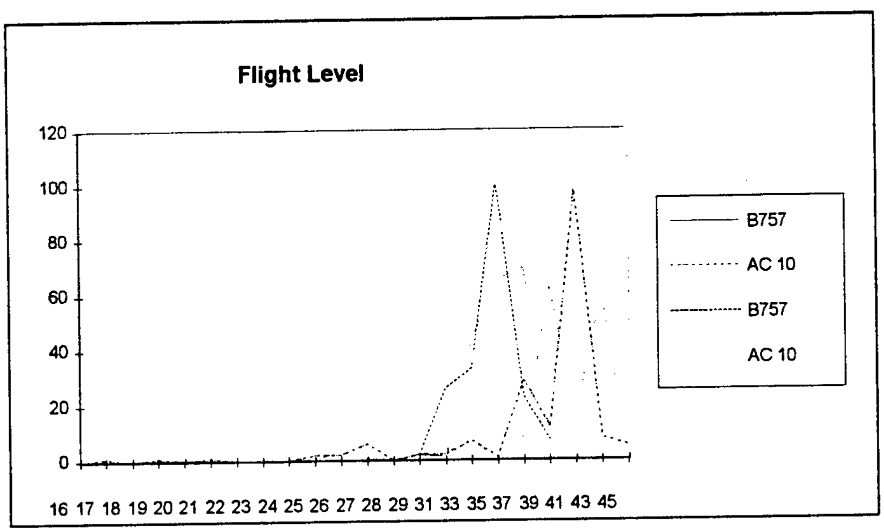
Appendix D

B757 Vs. NICE-JET (Speeds and Flight Levels)

D1. The following chart shows the Mach number comparisons between the B757 (Type 8) and the NICE-JET (Type 10). These comparisons were completed with historical data from the NAT.



D2. The following chart shows the flight level comparisons between the B757 and the NICE-JET (Type 10). Flight levels are separated by direction of travel. These comparisons were completed with historical data from the NAT.



Appendix E

Cumulative Distribution for A/C Types by Region, Direction, Season and Year

Summer 1996

Summer - East	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.270	0.568	0.649	0.649	0.703	0.946	0.973	0.973	0.973	1.000	1.000	0.014
EUR-NAM/EAST	0.273	0.487	0.585	0.669	0.722	0.760	0.816	0.873	0.923	0.977	1.000	0.507
EUR-NAM/MIDWEST	0.375	0.612	0.746	0.778	0.807	0.847	0.887	0.933	0.954	0.978	1.000	0.063
EUR-NAM/WEST	0.206	0.401	0.463	0.465	0.465	0.786	0.944	0.947	0.997	0.997	1.000	0.050
EUR/SCAN-CAR/BER	0.338	0.547	0.738	0.782	0.824	0.867	0.929	0.931	0.989	1.000	1.000	0.045
IBE-CAN	0.036	0.036	0.214	0.500	0.500	0.500	0.500	0.857	0.857	1.000	1.000	0.009
IBE-CAR	0.191	0.282	0.736	0.764	0.845	0.845	0.845	0.909	0.982	1.000	1.000	0.027
IBE-USA/BER	0.183	0.297	0.429	0.489	0.808	0.808	0.808	0.945	0.986	1.000	1.000	0.127
SCAN-NAM	0.475	0.493	0.516	0.525	0.531	0.531	0.576	0.916	0.916	1.000	1.000	0.154
EUR/SCAN/IBE-NAM/ALASKA	0.043	0.787	0.851	0.851	0.872	1.000	1.000	1.000	1.000	1.000	1.000	0.005
Total	**0.294**	**0.494**	**0.607**	**0.666**	**0.719**	**0.776**	**0.832**	**0.902**	**0.944**	**0.985**	**1.000**	**1.000**

Summer - West	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.289	0.421	0.447	0.447	0.632	0.947	0.974	0.974	0.974	1.000	1.000	0.013
EUR-NAM/EAST	0.266	0.483	0.579	0.665	0.716	0.757	0.811	0.874	0.922	0.977	1.000	0.561
EUR-NAM/MIDWEST	0.391	0.628	0.761	0.789	0.820	0.853	0.905	0.943	0.964	0.977	1.000	0.076
EUR-NAM/WEST	0.195	0.384	0.460	0.468	0.468	0.797	0.947	0.947	1.000	1.000	1.000	0.006
EUR/SCAN-CAR/BER	0.359	0.568	0.761	0.795	0.841	0.889	0.955	0.957	1.000	1.000	1.000	0.045
IBE-CAN	0.077	0.077	0.346	0.731	0.731	0.731	0.731	0.885	0.885	1.000	1.000	0.000
IBE-CAR	0.248	0.314	0.810	0.810	0.901	0.901	0.901	0.942	0.992	1.000	1.000	0.019
IBE-USA/BER	0.183	0.304	0.439	0.487	0.765	0.770	0.770	0.917	0.965	1.000	1.000	0.153
SCAN-NAM	0.449	0.460	0.490	0.496	0.512	0.512	0.562	0.898	0.898	1.000	1.000	0.121
EUR/SCAN/IBE-NAM/ALASKA	0.024	0.857	0.929	0.929	0.952	1.000	1.000	1.000	1.000	1.000	1.000	0.006
Total	**0.294**	**0.491**	**0.607**	**0.665**	**0.718**	**0.775**	**0.832**	**0.904**	**0.944**	**0.984**	**1.000**	**1.000**

* Notes:
1. NICE = NICE-JET as discussed in the report.
2. Mil = Military aircraft has a separate distribution from the commercial aircraft. It is included in the tables as part of the aircraft distribution.

Winter 1996

Winter - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.314	0.486	0.514	0.514	0.714	1.000	1.000	1.000	1.000	1.000	1.000	0.000
EUR-NAM/EAST	0.289	0.515	0.613	0.680	0.726	0.765	0.829	0.877	0.931	0.974	1.000	0.530
EUR-NAM/MIDWEST	0.405	0.661	0.812	0.820	0.825	0.853	0.921	0.924	0.955	0.972	1.000	0.050
EUR-NAM/WEST	0.202	0.440	0.476	0.488	0.488	0.795	0.949	0.952	1.000	1.000	1.000	0.050
EUR/SCAN-CAR/BER	0.339	0.554	0.738	0.780	0.806	0.853	0.932	0.944	0.996	1.000	1.000	0.059
IBE-CAN	0.000	0.000	0.280	0.680	0.680	0.680	0.680	0.760	0.760	1.000	1.000	0.000
IBE-CAR	0.155	0.196	0.691	0.742	0.835	0.835	0.835	0.876	0.969	1.000	1.000	0.009
IBE-USA/BER	0.228	0.339	0.487	0.540	0.783	0.783	0.783	0.937	0.942	1.000	1.000	0.201
SCAN-NAM	0.519	0.546	0.573	0.573	0.573	0.573	0.619	0.931	0.931	1.000	1.000	0.100
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.815	0.815	0.815	0.815	0.963	0.981	0.981	0.981	1.000	1.000	0.000
Total	**0.307**	**0.522**	**0.638**	**0.686**	**0.728**	**0.785**	**0.851**	**0.904**	**0.949**	**0.983**	**1.000**	**1.000**

Winter - West	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.333	0.481	0.519	0.556	0.704	1.000	1.000	1.000	1.000	1.000	1.000	0.009
EUR-NAM/EAST	0.285	0.493	0.594	0.658	0.712	0.755	0.818	0.871	0.923	0.974	1.000	0.498
EUR-NAM/MIDWEST	0.407	0.653	0.781	0.804	0.819	0.849	0.915	0.920	0.960	0.970	1.000	0.087
EUR-NAM/WEST	0.218	0.440	0.476	0.482	0.482	0.818	0.954	0.954	1.000	1.000	1.000	0.039
EUR/SCAN-CAR/BER	0.333	0.538	0.745	0.780	0.817	0.856	0.948	0.948	0.993	1.000	1.000	0.048
IBE-CAN	0.067	0.067	0.267	0.600	0.600	0.600	0.600	0.933	0.933	1.000	1.000	0.000
IBE-CAR	0.144	0.186	0.722	0.753	0.825	0.825	0.825	0.918	0.969	1.000	1.000	0.022
IBE-USA/BER	0.206	0.320	0.521	0.572	0.763	0.763	0.763	0.923	0.948	1.000	1.000	0.188
SCAN-NAM	0.474	0.484	0.543	0.543	0.554	0.557	0.599	0.889	0.889	1.000	1.000	0.109
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.950	0.975	0.975	0.975	0.975	1.000	1.000	1.000	1.000	1.000	0.000
Total	**0.305**	**0.504**	**0.627**	**0.673**	**0.719**	**0.776**	**0.842**	**0.899**	**0.943**	**0.982**	**1.000**	**1.000**

Summer 2000

Summer - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.270	0.478	0.519	0.519	0.573	0.861	0.888	0.888	0.919	0.946	1.000	0.014
EUR-NAM/EAST	0.273	0.423	0.472	0.514	0.567	0.637	0.693	0.750	0.847	0.901	1.000	0.507
EUR-NAM/MIDWEST	0.375	0.541	0.608	0.624	0.653	0.729	0.769	0.815	0.880	0.905	1.000	0.063
EUR-NAM/WEST	0.206	0.343	0.373	0.375	0.375	0.725	0.882	0.885	0.959	0.959	1.000	0.050
EUR/SCAN-CAR/BER	0.338	0.484	0.580	0.602	0.644	0.718	0.780	0.782	0.897	0.908	1.000	0.045
IBE-CAN	0.036	0.036	0.125	0.268	0.268	0.268	0.268	0.625	0.718	0.861	1.000	0.009
IBE-CAR	0.191	0.255	0.482	0.495	0.577	0.591	0.591	0.655	0.828	0.846	1.000	0.027
IBE-USA/BER	0.183	0.263	0.329	0.358	0.678	0.695	0.695	0.832	0.917	0.931	1.000	0.127
SCAN-NAM	0.475	0.487	0.499	0.504	0.510	0.512	0.557	0.897	0.905	0.988	1.000	0.154
EUR/SCAN/IBE-NAM/ALASKA	0.043	0.564	0.596	0.596	0.617	0.856	0.856	0.856	0.906	0.906	1.000	0.005
Total	**0.294**	**0.434**	**0.490**	**0.520**	**0.573**	**0.660**	**0.716**	**0.785**	**0.872**	**0.913**	**1.000**	**1.000**
Summer - West	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.289	0.382	0.395	0.395	0.579	0.914	0.941	0.941	0.953	0.979	1.000	0.013
EUR-NAM/EAST	0.266	0.418	0.466	0.509	0.560	0.633	0.687	0.750	0.846	0.901	1.000	0.561
EUR-NAM/MIDWEST	0.391	0.557	0.623	0.637	0.668	0.737	0.789	0.826	0.892	0.905	1.000	0.076
EUR-NAM/WEST	0.195	0.328	0.365	0.369	0.369	0.726	0.877	0.877	0.956	0.956	1.000	0.006
EUR/SCAN-CAR/BER	0.359	0.505	0.602	0.619	0.665	0.744	0.810	0.812	0.911	0.911	1.000	0.045
IBE-CAN	0.077	0.077	0.212	0.404	0.404	0.404	0.404	0.558	0.688	0.804	1.000	0.000
IBE-CAR	0.248	0.294	0.542	0.542	0.633	0.643	0.643	0.684	0.836	0.845	1.000	0.019
IBE-USA/BER	0.183	0.268	0.335	0.359	0.637	0.660	0.660	0.808	0.898	0.933	1.000	0.153
SCAN-NAM	0.449	0.457	0.472	0.475	0.491	0.493	0.543	0.878	0.886	0.988	1.000	0.121
EUR/SCAN/IBE-NAM/ALASKA	0.024	0.607	0.643	0.643	0.667	0.839	0.839	0.839	0.895	0.895	1.000	0.006
Total	**0.294**	**0.432**	**0.490**	**0.519**	**0.572**	**0.659**	**0.715**	**0.787**	**0.872**	**0.913**	**1.000**	**1.000**

Winter 2000

Winter - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.314	0.434	0.449	0.449	0.649	0.960	0.960	0.960	0.974	0.974	1.000	0.000
EUR-NAM/EAST	0.289	0.447	0.496	0.530	0.575	0.649	0.713	0.760	0.859	0.902	1.000	0.530
EUR-NAM/MIDWEST	0.405	0.584	0.660	0.664	0.669	0.735	0.803	0.806	0.882	0.899	1.000	0.050
EUR-NAM/WEST	0.202	0.368	0.386	0.392	0.392	0.735	0.889	0.892	0.962	0.962	1.000	0.050
EUR/SCAN-CAR/BER	0.339	0.489	0.582	0.602	0.629	0.708	0.787	0.798	0.907	0.911	1.000	0.059
IBE-CAN	0.000	0.000	0.140	0.340	0.340	0.340	0.340	0.420	0.556	0.796	1.000	0.000
IBE-CAR	0.155	0.184	0.431	0.457	0.549	0.556	0.556	0.597	0.801	0.832	1.000	0.009
IBE-USA/BER	0.228	0.305	0.379	0.406	0.649	0.666	0.666	0.819	0.870	0.929	1.000	0.201
SCAN-NAM	0.519	0.538	0.552	0.552	0.552	0.556	0.602	0.913	0.920	0.989	1.000	0.100
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.570	0.570	0.570	0.570	0.841	0.859	0.859	0.900	0.919	1.000	0.000
Total	**0.307**	**0.457**	**0.516**	**0.539**	**0.581**	**0.670**	**0.737**	**0.789**	**0.878**	**0.912**	**1.000**	**1.000**
Winter - West	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.333	0.437	0.456	0.474	0.622	0.941	0.941	0.941	0.963	0.963	1.000	0.009
EUR-NAM/EAST	0.285	0.431	0.481	0.513	0.567	0.641	0.705	0.757	0.853	0.904	1.000	0.498
EUR-NAM/MIDWEST	0.407	0.579	0.643	0.655	0.670	0.736	0.803	0.808	0.890	0.900	1.000	0.087
EUR-NAM/WEST	0.218	0.373	0.391	0.394	0.394	0.763	0.900	0.900	0.965	0.965	1.000	0.039
EUR/SCAN-CAR/BER	0.333	0.476	0.580	0.597	0.634	0.704	0.796	0.796	0.899	0.907	1.000	0.048
IBE-CAN	0.067	0.067	0.167	0.333	0.333	0.333	0.333	0.667	0.773	0.840	1.000	0.000
IBE-CAR	0.144	0.173	0.441	0.457	0.529	0.535	0.535	0.628	0.795	0.826	1.000	0.022
IBE-USA/BER	0.206	0.286	0.386	0.412	0.603	0.620	0.620	0.779	0.861	0.913	1.000	0.188
SCAN-NAM	0.474	0.481	0.511	0.511	0.521	0.526	0.568	0.858	0.871	0.981	1.000	0.109
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.665	0.678	0.678	0.678	0.820	0.845	0.845	0.898	0.898	1.000	0.000
Total	**0.305**	**0.445**	**0.506**	**0.529**	**0.575**	**0.662**	**0.727**	**0.785**	**0.872**	**0.912**	**1.000**	**1.000**

Summer 2005

Summer - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.324	0.473	0.473	0.473	0.473	0.761	0.788	0.788	0.865	0.892	1.000	0.014
EUR-NAM/EAST	0.383	0.490	0.490	0.490	0.490	0.560	0.616	0.616	0.771	0.825	1.000	0.507
EUR-NAM/MIDWEST	0.451	0.569	0.569	0.569	0.569	0.645	0.685	0.685	0.807	0.831	1.000	0.063
EUR-NAM/WEST	0.209	0.306	0.306	0.306	0.306	0.656	0.814	0.814	0.920	0.920	1.000	0.050
EUR/SCAN-CAR/BER	0.382	0.487	0.487	0.487	0.487	0.560	0.622	0.622	0.806	0.817	1.000	0.045
IBE-CAN	0.393	0.393	0.393	0.393	0.393	0.393	0.393	0.393	0.579	0.721	1.000	0.009
IBE-CAR	0.336	0.382	0.382	0.382	0.382	0.395	0.395	0.395	0.675	0.693	1.000	0.027
IBE-USA/BER	0.639	0.696	0.696	0.696	0.696	0.713	0.713	0.713	0.848	0.862	1.000	0.127
SCAN-NAM	0.821	0.830	0.830	0.830	0.830	0.833	0.877	0.877	0.893	0.977	1.000	0.154
EUR/SCAN/IBE-NAM/ALASKA	0.064	0.436	0.436	0.436	0.436	0.676	0.676	0.676	0.813	0.813	1.000	0.005
Total	**0.416**	**0.516**	**0.516**	**0.516**	**0.516**	**0.603**	**0.659**	**0.659**	**0.800**	**0.841**	**1.000**	**1.000**
Summer - West	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.474	0.539	0.539	0.539	0.539	0.875	0.901	0.901	0.932	0.958	1.000	0.013
EUR-NAM/EAST	0.380	0.488	0.488	0.488	0.488	0.562	0.615	0.615	0.769	0.824	1.000	0.561
EUR-NAM/MIDWEST	0.459	0.577	0.577	0.577	0.577	0.646	0.698	0.698	0.820	0.833	1.000	0.076
EUR-NAM/WEST	0.195	0.290	0.290	0.290	0.290	0.647	0.797	0.797	0.912	0.912	1.000	0.006
EUR/SCAN-CAR/BER	0.407	0.511	0.511	0.511	0.511	0.590	0.656	0.656	0.822	0.822	1.000	0.045
IBE-CAN	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.492	0.608	1.000	0.000
IBE-CAR	0.380	0.413	0.413	0.413	0.413	0.423	0.423	0.423	0.681	0.689	1.000	0.019
IBE-USA/BER	0.609	0.670	0.670	0.670	0.670	0.692	0.692	0.692	0.831	0.866	1.000	0.153
SCAN-NAM	0.801	0.806	0.806	0.806	0.806	0.808	0.858	0.858	0.874	0.976	1.000	0.121
EUR/SCAN/IBE-NAM/ALASKA	0.048	0.464	0.464	0.464	0.464	0.637	0.637	0.637	0.790	0.790	1.000	0.006
Total	**0.419**	**0.518**	**0.518**	**0.518**	**0.518**	**0.604**	**0.661**	**0.661**	**0.800**	**0.841**	**1.000**	**1.000**

Winter 2005

Winter - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.514	0.600	0.600	0.600	0.600	0.911	0.911	0.911	0.949	0.949	1.000	0.000
EUR-NAM/EAST	0.382	0.495	0.495	0.495	0.495	0.569	0.632	0.632	0.787	0.830	1.000	0.530
EUR-NAM/MIDWEST	0.413	0.541	0.541	0.541	0.541	0.608	0.676	0.676	0.809	0.825	1.000	0.050
EUR-NAM/WEST	0.205	0.324	0.324	0.324	0.324	0.667	0.820	0.820	0.923	0.923	1.000	0.050
EUR/SCAN-CAR/BER	0.377	0.484	0.484	0.484	0.484	0.563	0.642	0.642	0.818	0.821	1.000	0.059
IBE-CAN	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.352	0.592	1.000	0.000
IBE-CAR	0.289	0.309	0.309	0.309	0.309	0.315	0.315	0.315	0.633	0.664	1.000	0.009
IBE-USA/BER	0.624	0.680	0.680	0.680	0.680	0.697	0.697	0.697	0.799	0.857	1.000	0.201
SCAN-NAM	0.831	0.844	0.844	0.844	0.844	0.848	0.894	0.894	0.909	0.978	1.000	0.100
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.407	0.407	0.407	0.407	0.678	0.696	0.696	0.819	0.837	1.000	0.000
Total	**0.402**	**0.509**	**0.509**	**0.509**	**0.509**	**0.598**	**0.664**	**0.664**	**0.807**	**0.841**	**1.000**	**1.000**
Winter - West	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.481	0.556	0.556	0.556	0.556	0.874	0.874	0.874	0.926	0.926	1.000	0.009
EUR-NAM/EAST	0.392	0.496	0.496	0.496	0.496	0.570	0.633	0.633	0.782	0.834	1.000	0.498
EUR-NAM/MIDWEST	0.427	0.550	0.550	0.550	0.550	0.617	0.683	0.683	0.820	0.830	1.000	0.087
EUR-NAM/WEST	0.218	0.329	0.329	0.329	0.329	0.698	0.835	0.835	0.930	0.930	1.000	0.039
EUR/SCAN-CAR/BER	0.370	0.472	0.472	0.472	0.472	0.542	0.634	0.634	0.806	0.814	1.000	0.048
IBE-CAN	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.613	0.680	1.000	0.000
IBE-CAR	0.309	0.330	0.330	0.330	0.330	0.336	0.336	0.336	0.621	0.652	1.000	0.022
IBE-USA/BER	0.557	0.613	0.613	0.613	0.613	0.630	0.630	0.630	0.774	0.826	1.000	0.188
SCAN-NAM	0.775	0.780	0.780	0.780	0.780	0.785	0.827	0.827	0.852	0.963	1.000	0.109
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.475	0.475	0.475	0.475	0.618	0.643	0.643	0.795	0.795	1.000	0.000
Total	**0.409**	**0.508**	**0.508**	**0.508**	**0.508**	**0.595**	**0.661**	**0.661**	**0.802**	**0.841**	**1.000**	**1.000**

Summer 2010

Summer - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.324	0.324	0.324	0.324	0.324	0.612	0.639	0.639	0.776	0.803	1.000	0.014
EUR-NAM/EAST	0.383	0.383	0.383	0.383	0.383	0.453	0.509	0.509	0.707	0.761	1.000	0.507
EUR-NAM/MIDWEST	0.451	0.451	0.451	0.451	0.451	0.526	0.566	0.566	0.736	0.760	1.000	0.063
EUR-NAM/WEST	0.209	0.209	0.209	0.209	0.209	0.559	0.716	0.716	0.861	0.861	1.000	0.050
EUR/SCAN-CAR/BER	0.382	0.382	0.382	0.382	0.382	0.456	0.518	0.518	0.743	0.754	1.000	0.045
IBE-CAN	0.393	0.393	0.393	0.393	0.393	0.393	0.393	0.393	0.579	0.721	1.000	0.009
IBE-CAR	0.336	0.336	0.336	0.336	0.336	0.350	0.350	0.350	0.647	0.665	1.000	0.027
IBE-USA/BER	0.639	0.639	0.639	0.639	0.639	0.656	0.656	0.656	0.814	0.828	1.000	0.127
SCAN-NAM	0.821	0.821	0.821	0.821	0.821	0.824	0.868	0.868	0.888	0.971	1.000	0.154
EUR/SCAN/IBE-NAM/ALASKA	0.064	0.064	0.064	0.064	0.064	0.303	0.303	0.303	0.589	0.589	1.000	0.005
Total	**0.416**	**0.416**	**0.416**	**0.416**	**0.416**	**0.503**	**0.559**	**0.559**	**0.740**	**0.781**	**1.000**	**1.000**
Summer - West	**B767**	**B747**	**DC10**	**L1011**	**EA31**	**B74F**	**MD11**	**B757**	**EA34**	**NICE***	**B777**	**Mil***
AFR-NAM/CAR/BER	0.474	0.474	0.474	0.474	0.474	0.809	0.836	0.836	0.892	0.918	1.000	0.013
EUR-NAM/EAST	0.380	0.380	0.380	0.380	0.380	0.453	0.507	0.507	0.704	0.759	1.000	0.561
EUR-NAM/MIDWEST	0.459	0.459	0.459	0.459	0.459	0.528	0.580	0.580	0.749	0.762	1.000	0.076
EUR-NAM/WEST	0.195	0.195	0.195	0.195	0.195	0.552	0.703	0.703	0.855	0.855	1.000	0.006
EUR/SCAN-CAR/BER	0.407	0.407	0.407	0.407	0.407	0.486	0.552	0.552	0.759	0.759	1.000	0.045
IBE-CAN	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.492	0.608	1.000	0.000
IBE-CAR	0.380	0.380	0.380	0.380	0.380	0.390	0.390	0.390	0.661	0.669	1.000	0.019
IBE-USA/BER	0.609	0.609	0.609	0.609	0.609	0.631	0.631	0.631	0.795	0.830	1.000	0.153
SCAN-NAM	0.801	0.801	0.801	0.801	0.801	0.802	0.852	0.852	0.870	0.973	1.000	0.121
EUR/SCAN/IBE-NAM/ALASKA	0.048	0.048	0.048	0.048	0.048	0.220	0.220	0.220	0.540	0.540	1.000	0.006
Total	**0.419**	**0.419**	**0.419**	**0.419**	**0.419**	**0.506**	**0.562**	**0.562**	**0.741**	**0.781**	**1.000**	**1.000**

Winter - East	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.514	0.514	0.514	0.514	0.514	0.826	0.826	0.826	0.897	0.897	1.000	0.000
EUR-NAM/EAST	0.382	0.382	0.382	0.382	0.382	0.456	0.520	0.520	0.719	0.762	1.000	0.530
EUR-NAM/MIDWEST	0.413	0.413	0.413	0.413	0.413	0.480	0.548	0.548	0.732	0.749	1.000	0.050
EUR-NAM/WEST	0.205	0.205	0.205	0.205	0.205	0.548	0.701	0.701	0.852	0.852	1.000	0.050
EUR/SCAN-CAR/BER	0.377	0.377	0.377	0.377	0.377	0.456	0.535	0.535	0.753	0.757	1.000	0.059
IBE-CAN	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.352	0.592	1.000	0.000
IBE-CAR	0.289	0.289	0.289	0.289	0.289	0.295	0.295	0.295	0.621	0.652	1.000	0.009
IBE-USA/BER	0.624	0.624	0.624	0.624	0.624	0.641	0.641	0.641	0.766	0.824	1.000	0.201
SCAN-NAM	0.831	0.831	0.831	0.831	0.831	0.835	0.881	0.881	0.901	0.970	1.000	0.100
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.000	0.000	0.000	0.000	0.270	0.289	0.289	0.574	0.593	1.000	0.000
Total	**0.402**	**0.402**	**0.402**	**0.402**	**0.402**	**0.491**	**0.557**	**0.557**	**0.743**	**0.777**	**1.000**	**1.000**

Winter - West	B767	B747	DC10	L1011	EA31	B74F	MD11	B757	EA34	NICE*	B777	Mil*
AFR-NAM/CAR/BER	0.481	0.481	0.481	0.481	0.481	0.800	0.800	0.800	0.881	0.881	1.000	0.009
EUR-NAM/EAST	0.392	0.392	0.392	0.392	0.392	0.466	0.529	0.529	0.720	0.771	1.000	0.498
EUR-NAM/MIDWEST	0.427	0.427	0.427	0.427	0.427	0.494	0.560	0.560	0.747	0.756	1.000	0.087
EUR-NAM/WEST	0.218	0.218	0.218	0.218	0.218	0.587	0.724	0.724	0.864	0.864	1.000	0.039
EUR/SCAN-CAR/BER	0.370	0.370	0.370	0.370	0.370	0.439	0.532	0.532	0.745	0.752	1.000	0.048
IBE-CAN	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.613	0.680	1.000	0.000
IBE-CAR	0.309	0.309	0.309	0.309	0.309	0.315	0.315	0.315	0.608	0.639	1.000	0.022
IBE-USA/BER	0.557	0.557	0.557	0.557	0.557	0.574	0.574	0.574	0.740	0.792	1.000	0.188
SCAN-NAM	0.775	0.775	0.775	0.775	0.775	0.780	0.822	0.822	0.849	0.960	1.000	0.109
EUR/SCAN/IBE-NAM/ALASKA	0.000	0.000	0.000	0.000	0.000	0.143	0.168	0.168	0.510	0.510	1.000	0.000
Total	**0.409**	**0.409**	**0.409**	**0.409**	**0.409**	**0.495**	**0.561**	**0.561**	**0.742**	**0.781**	**1.000**	**1.000**

Appendix F
Triangular Distributions for Take Off Weight in Pounds

	AC1			AC2			AC3			AC4		
Region	min	likely	max	min	likely	max	min	likely	max	min	likely	max
AFR-NAM/CAR/BER	377000	392139	418000	754000	784000	820000	533000	554000	580000	474000	493000	516000
EUR-NAM/EAST	268000	334068	418000	535000	686380	820000	379000	487922	580000	337000	433000	516000
EUR-NAM/MIDWEST	279000	334513	418000	560000	689686	820000	396000	543821	580000	352000	440000	516000
EUR-NAM/WEST	318000	359094	418000	636000	724098	820000	450000	516000	580000	400000	459000	516000
EUR/SCAN-CAR/BER	311000	368000	418000	622000	729686	820000	440000	524302	580000	391000	463000	516000
EUR/SCAN/IBE-NAM/ALASKA	356000	387000	418000	712500	76250	820000	504000	542000	580000	448000	482000	516000
IBE-CAN	287000	349000	418000	574000	697000	820000	406000	493000	580000	361000	439000	516000
IBE-CAR	303000	357000	418000	609000	713000	820000	429000	505000	580000	382000	449000	516000
IBE-USA/BER	324000	363539	418000	649000	665000	820000	459000	509000	580000	408000	453000	516000
SCAN-NAM	335000	373468	418000	671000	734000	820000	475000	519000	580000	422000	462000	516000

	AC5			AC6			AC7			AC8		
Region	min	likely	max	min	likely	max	min	likely	max	min	likely	max
AFR-NAM/CAR/BER	334000	347000	363000	809000	841000	880000	576000	599000	627000	234000	244000	255000
EUR-NAM/EAST	237000	305000	363000	574000	739000	880000	409000	501148	627000	166000	214000	255000
EUR-NAM/MIDWEST	248000	310000	363000	601000	767156	880000	428000	540217	627000	174000	218000	255000
EUR-NAM/WEST	282000	323000	363000	683000	771977	880000	486000	557000	627000	198000	227000	255000
EUR/SCAN-CAR/BER	275000	326000	363000	667000	801037	880000	475000	562000	627000	193000	229000	255000
EUR/SCAN/IBE-NAM/ALASKA	315500	339250	363000	764500	822500	880000	544500	585750	627000	221500	238250	255000
IBE-CAN	254000	309000	363000	616000	748000	880000	439000	533000	627000	179000	217000	255000
IBE-CAR	269000	316000	363000	651000	766000	880000	464000	545000	627000	189000	222000	255000
IBE-USA/BER	287000	319000	363000	696000	773000	880000	496000	551000	627000	202000	224000	255000
SCAN-NAM	297000	325000	363000	720000	788000	880000	513000	561000	627000	209000	228000	255000

	AC9			AC10			AC11		
Region	min	likely	max	min	likely	max	min	likely	max
AFR-NAM/CAR/BER	526000	547000	572000	41000	43000	45000	506000	526000	550000
EUR-NAM/EAST	373000	492628	572000	29000	38000	45000	359000	462000	550000
EUR-NAM/MIDWEST	391000	473133	572000	31000	38000	45000	376000	469000	550000
EUR-NAM/WEST	444000	496328	572000	35000	40000	45000	427000	489000	550000
EUR/SCAN-CAR/BER	434000	513000	572000	34000	40000	45000	417000	493000	550000
EUR/SCAN/IBE-NAM/ALASKA	497000	534500	572000	39000	42000	45000	478000	514000	550000
IBE-CAN	400000	486000	572000	31000	38000	45000	385000	468000	550000
IBE-CAR	423000	498000	572000	33000	39000	45000	407000	479000	550000
IBE-USA/BER	452000	502000	572000	36000	40000	45000	435000	483000	550000
SCAN-NAM	468000	512000	572000	37000	40000	45000	450000	492000	550000

Appendix G
Flight Events for January 4, 2005

G1. The first 200 flight events of January 4, 2005 are presented below. The columns contain the following data:

a. Day

b. Nat entry time (minutes)

c. Region designation

d. Direction designator

e. Origin airport ICAO code

f. Destination airport ICAO code

g. Aircraft type code

h. Civilian / Military designator

i. Cruise Mach (* 1000)

j. Take off weight (lbs)

0	1129	4	0	KLSV	ETNG	1	0	800	354252
0	1148	5	0	TNCC	EHAM	1	0	810	365216
0	1191	5	0	SVMI	EDDF	9	0	820	514728
0	1198	5	0	TFFR	LFRS	1	0	800	396304
0	1208	10	0	PAFA	LFPG	9	0	830	545897
0	1209	5	0	SVMI	EDDF	6	0	850	801019
0	1213	10	0	PAFA	LFPG	2	0	860	746402
0	1245	9	0	KJFK	UUEE	1	0	820	371044
0	1252	2	0	CYMX	LLBG	1	0	810	363005
0	1254	9	0	KJFK	UUEE	1	0	810	382233
0	1258	10	0	PAFA	EDDF	6	0	850	824961
0	1262	5	0	TFFR	LFPO	1	0	800	373309
0	1269	2	0	KJFK	LGAT	11	0	840	406009
0	1271	5	0	SOCA	LFPG	11	0	840	527678
0	1272	5	0	TFFF	LFPO	9	0	820	512684
0	1274	2	1	EGNX	KSDF	6	0	840	736415
0	1274	5	0	TFFR	LFRS	2	0	850	767286
0	1280	5	0	TFFR	LFRS	1	0	800	407268
0	1281	2	0	KCVG	EDDF	9	0	820	492249
0	1281	2	1	EGNX	KSDF	9	0	810	400813
0	1283	5	0	TNCC	EHAM	1	0	810	382944
0	1283	10	0	PANC	EGLL	9	0	810	548856
0	1288	2	0	KRSW	EDDL	9	0	820	545640
0	1295	5	0	MDPP	EDDL	2	0	830	689316
0	1297	5	0	TFFF	LFPO	1	0	800	385482
0	1312	3	0	KORD	LIRF	1	0	800	345177
0	1322	4	0	KLAX	EDDL	6	0	850	773729
0	1324	2	0	KATL	LOWW	1	0	800	335826
0	1324	2	0	KDFW	EGKK	9	0	810	455166
0	1324	4	0	KSFO	EGLL	1	0	800	399515

0	1326	2	0	KIAH	EGKK	6	0	850	660189
0	1330	5	0	TFFF	LFPO	9	0	820	532587
0	1330	5	0	TFFF	LFML	1	0	800	338458
0	1330	9	0	KEWR	EKCH	11	0	840	497486
0	1331	2	0	KWRI	EDAF	8	1	800	248739
0	1334	9	0	KSEA	EKCH	1	0	810	394767
0	1335	7	0	MUVR	LEMD	1	0	800	365608
0	1336	2	0	KIAH	LFPG	9	0	820	442825
0	1336	5	0	TFFF	LFBO	6	0	850	814798
0	1337	8	0	KMIA	LEMD	11	0	830	466859
0	1338	5	0	TFFF	LFBO	1	0	800	390900
0	1339	2	0	KEWR	LIMC	9	0	820	497571
0	1339	4	0	KSFO	EGLL	7	0	830	587896
0	1339	5	0	TBPB	EGKK	11	0	850	489245
0	1340	3	0	CYYZ	EDDF	1	0	800	393235
0	1346	2	0	KIAH	EHAM	7	0	830	512811
0	1347	2	0	KIAD	EDDF	2	0	840	749351
0	1349	2	0	KATL	EHAM	1	0	800	290203
0	1349	2	0	KMCO	EGKK	9	0	830	448414
0	1351	2	1	EGGW	KTEB	9	0	810	436443
0	1352	2	0	KEWR	LFPG	7	0	820	578903
0	1353	2	1	LLBG	CYMX	1	0	810	293744
0	1354	2	0	CYFB	BGSF	10	0	800	33488
0	1354	5	0	MUVR	LIPX	6	0	850	825619
0	1355	2	0	KCVG	EDDF	9	0	830	554253
0	1356	2	0	KJFK	EBBR	11	0	840	424668
0	1359	3	0	CYYZ	EDDF	9	0	820	453987
0	1359	5	0	MDPP	LOWW	7	0	840	517781
0	1362	2	0	KIAH	EGKK	7	0	830	483858
0	1363	4	0	KLAX	EDDF	11	0	840	532935
0	1363	5	0	SVMI	LIRF	1	0	810	338884
0	1363	7	0	MDSD	LEMD	1	0	800	352296
0	1364	5	0	TFFF	LFPO	11	0	840	505639
0	1365	3	0	KORD	EDDF	1	0	800	344669
0	1367	5	0	TFFF	LFPO	1	0	810	322768
0	1368	2	0	KMCO	EGCC	1	0	820	383129
0	1368	5	0	MUHA	EINN	9	0	810	513184
0	1369	2	0	KEWR	LIMC	1	0	800	301418
0	1370	5	0	TFFR	LFPO	1	0	810	354696
0	1371	2	0	KIAD	EDDF	11	0	840	381871
0	1372	5	0	TFFR	LFPO	1	0	810	393830
0	1373	2	0	KDOV	ETAR	2	1	820	710696
0	1376	2	0	KDFW	EGKK	1	0	810	357575
0	1380	2	0	KIAD	LFPG	11	0	840	507187
0	1382	2	0	KEWR	LFPO	9	0	810	398935
0	1382	5	0	TFFF	LFPO	9	0	830	486704
0	1383	2	0	KATL	EDDM	11	0	840	403994
0	1383	2	0	KJFK	EHAM	1	0	800	337831
0	1384	2	0	KIAD	LFPG	2	0	840	789645
0	1384	2	0	KJFK	EGCC	1	0	800	285874
0	1386	2	0	KIAD	LFPG	11	0	840	434861
0	1386	9	0	KEWR	ESSA	1	0	810	386916
0	1387	4	0	KLAX	EDDF	2	0	840	696362
0	1388	2	0	KJFK	EDDM	1	0	820	298561
0	1388	4	0	KLAX	EGLL	1	0	790	360032

0	1389	3	0	KORD	LSZH	1	0	800	341002
0	1390	2	0	KMIA	EGKK	1	0	810	349860
0	1390	2	1	LLBG	KJFK	2	0	840	611913
0	1391	2	0	KBOS	EGLL	1	0	810	320467
0	1393	2	0	KATL	EGKK	11	0	840	500105
0	1393	2	1	LIMF	KJFK	1	0	800	291338
0	1394	4	0	KLAX	EDDF	7	0	830	512291
0	1395	2	0	KIAD	EGLL	1	0	800	319224
0	1395	4	0	CYVR	EGLL	11	0	840	488232
0	1396	2	0	KMIA	EHAM	1	0	800	377353
0	1396	3	0	KDTW	EHAM	1	0	800	391513
0	1397	2	0	KATL	EHAM	11	0	840	374427
0	1397	2	0	KIAD	EHAM	1	0	820	315675
0	1398	2	0	KIAD	EDDF	7	0	830	512298
0	1400	2	0	KIAD	LSZH	1	0	800	314783
0	1400	3	0	KDTW	EHAM	1	0	800	290814
0	1400	9	0	KORD	ESSA	1	0	800	372950
0	1401	2	0	KMIA	EDDM	1	0	800	359549
0	1401	2	1	EGSS	KEWR	11	0	840	472250
0	1402	2	0	KPIT	EGKK	1	0	810	316509
0	1402	2	0	KPIT	EGKK	6	0	850	811971
0	1403	3	0	KDTW	EDDF	9	0	830	538372
0	1404	2	1	LLBG	KJFK	11	0	840	530856
0	1404	5	0	MUHA	LIMC	2	0	840	717260
0	1405	2	0	KATL	EHAM	7	0	830	486021
0	1408	2	0	KATL	EDDM	7	0	830	472447
0	1409	2	0	KIAD	EGLL	7	0	830	555607
0	1409	2	0	KJFK	EDDM	2	0	840	736221
0	1409	2	0	KMIA	EGKK	1	0	810	320028
0	1410	2	0	KJFK	LIRF	2	0	840	576190
0	1410	8	0	KATL	LEMD	1	0	800	345166
0	1413	2	0	KTPA	EHAM	9	0	810	533098
0	1413	9	0	KEWR	EKCH	1	0	800	343492
0	1414	2	0	KATL	EHAM	10	0	800	35957
0	1414	2	0	KBOS	EDDF	7	0	830	516063
0	1414	2	0	KDFW	EGKK	7	0	820	517091
0	1414	2	0	KDFW	EGKK	11	0	840	475994
0	1414	2	0	KJFK	LIRF	11	0	850	414364
0	1415	4	0	CYVR	EGLL	2	0	840	760258
0	1415	4	0	CYVR	EGLL	2	0	850	687943
0	1416	2	0	KIAD	EHAM	7	0	820	478226
0	1416	2	0	KJFK	LLBG	1	0	800	360692
0	1417	2	0	KBWI	EGKK	2	0	840	703099
0	1418	2	1	EGSS	KMEM	9	0	820	498246
0	1420	2	0	KIAD	EDDF	2	0	840	701288
0	1420	2	0	KJFK	LTBA	1	0	800	335912
0	1420	5	0	SKBO	EDDF	7	0	840	612050
0	1421	2	0	KCLT	EGKK	9	0	830	480104
0	1423	2	0	KBOS	EDDF	11	0	840	517334
0	1423	2	0	KEWR	LIRF	9	0	810	500623
0	1423	2	0	KJFK	EHAM	7	0	830	457988
0	1423	2	1	LLBG	KJFK	1	0	810	303805
0	1424	2	0	KJFK	LHBP	9	0	820	442985
0	1426	3	0	CYYZ	EDDF	1	0	800	367593
0	1427	2	0	KMIA	LFPG	1	0	800	337484

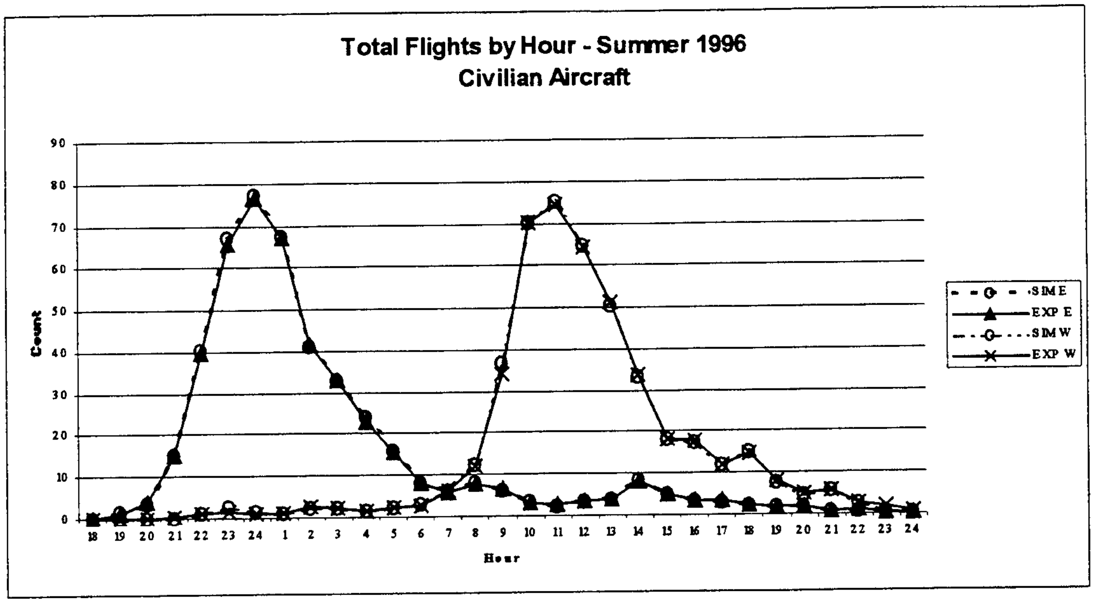
0	1427	5	0	TFFF	LFPO	1	0	800	399395
0	1428	2	0	KATL	EGKK	9	0	810	428797
0	1428	2	0	KIAD	EBBR	11	0	840	387867
0	1428	5	0	MDPP	EDDF	7	0	830	543214
0	1429	2	0	KIAD	LFPG	7	0	820	501165
0	1429	3	0	KDTW	LFPG	2	0	840	709754
0	1430	2	1	EGSS	KMEM	7	0	820	438291
0	1431	2	0	KJFK	EHAM	11	0	840	438149
0	1433	2	0	KJFK	LSZH	9	0	830	407555
0	1436	2	0	KDFW	LFPO	7	0	830	529813
0	1437	9	0	KJFK	UUEE	1	0	800	379414
0	1438	2	0	KATL	EDDM	10	0	800	37863
0	1438	2	0	KEWR	LFPO	2	0	840	767753
0	1438	4	0	CYVR	EGLL	6	0	850	737907
0	1439	3	0	CYYZ	LFPG	11	0	840	454796
0	1439	5	0	MDSD	LFPG	1	0	820	371165
1	1	2	0	KCVG	EGKK	1	0	800	375227
1	1	2	0	KJFK	LFPO	9	0	820	487548
1	1	2	0	KMIA	EDDF	1	0	800	294230
1	2	3	0	KORD	EGCC	1	0	800	350401
1	4	2	0	KIAD	EGLL	11	0	840	511093
1	5	2	0	KJFK	EGLL	2	0	840	696262
1	5	5	0	MUVR	LFPO	2	0	850	729083
1	5	8	0	KJFK	LPPT	1	0	800	386389
1	6	2	0	KJFK	EHAM	10	0	800	37161
1	6	3	0	CYYZ	EGPF	1	0	800	370129
1	8	4	0	KLAX	LSZH	6	0	850	750467
1	9	3	0	KORD	EGCC	6	0	850	674837
1	9	5	0	TFFF	LFPO	1	0	800	410792
1	10	2	0	KIAD	EGLL	11	0	840	374713
1	11	3	0	KORD	LSZH	11	0	840	520296
1	13	3	0	CYYZ	EGLL	9	0	820	473063
1	14	5	0	TFFR	LFPG	1	0	800	352486
1	15	2	0	KJFK	EDDT	6	0	840	755581
1	15	2	0	KJFK	LHBP	11	0	840	491335
1	15	2	0	KMIA	EDDF	1	0	800	305523
1	16	3	0	KORD	EGBB	1	0	810	321728
1	17	8	0	KMIA	LEMD	1	0	800	331966
1	18	2	0	KJFK	LIMC	1	0	800	347199
1	18	2	0	KPOB	EDAF	1	1	800	373613
1	18	8	0	KJFK	LEMD	10	0	800	42224
1	20	2	0	KJFK	EHAM	9	0	820	448448
1	21	3	0	CYYC	EDDF	1	0	820	376214
1	22	2	0	KBOS	LSZH	1	0	800	314634
1	23	3	0	KDTW	EHAM	9	0	830	549994
1	23	5	0	TFFR	LFPO	1	0	800	332435
1	24	2	0	KEWR	EGKK	6	0	850	805159
1	25	2	0	KCLT	EGKK	1	0	810	298846
1	27	2	0	KBGR	EGBB	6	0	850	640848
1	28	3	0	CYYZ	EHAM	2	0	860	673282
1	28	9	0	KJFK	EPWA	10	0	800	37392
1	29	4	0	KLAX	EGLL	6	0	850	801634
1	29	5	0	MKJS	EHAM	9	0	820	556739
1	29	5	0	TFFR	LFPG	10	0	800	38644
1	30	2	0	KJFK	LIRF	1	0	820	325645

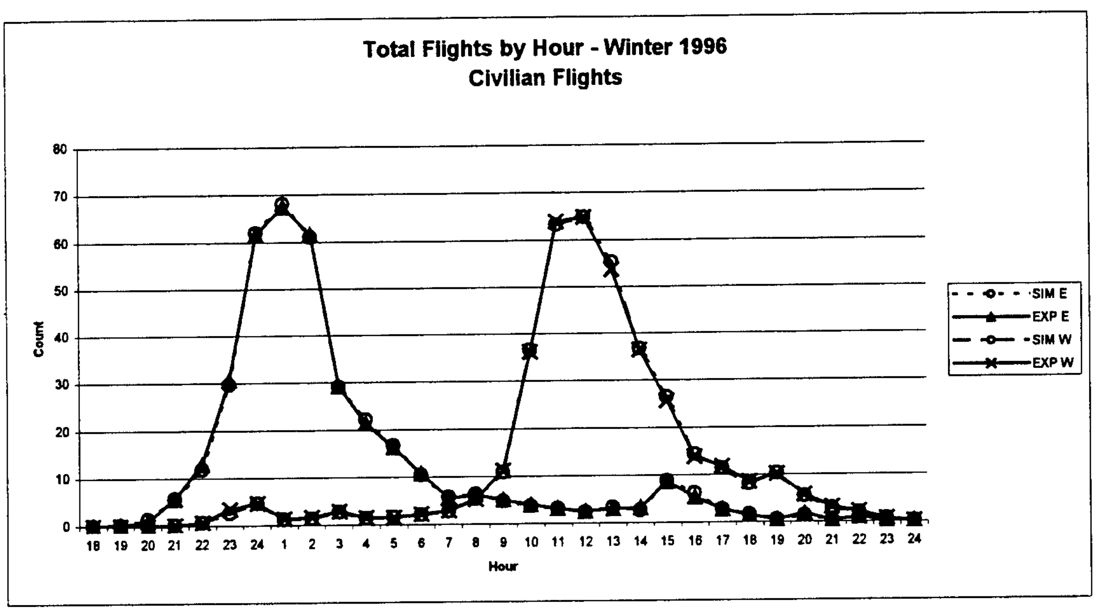
Appendix H

Verification and Validation of the Flight Event Generation

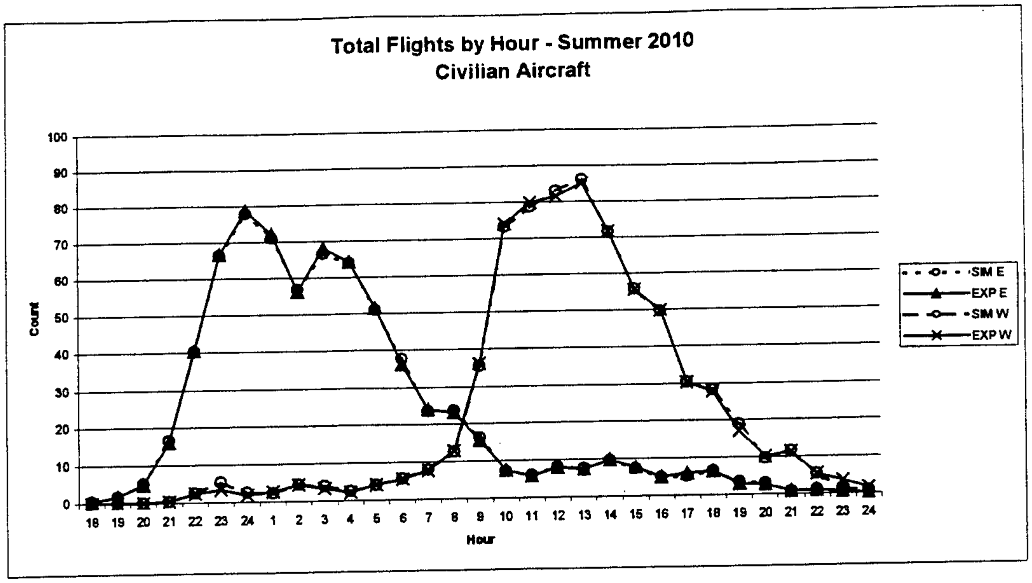
H1. Number of Flights Per Hour by Season and Direction

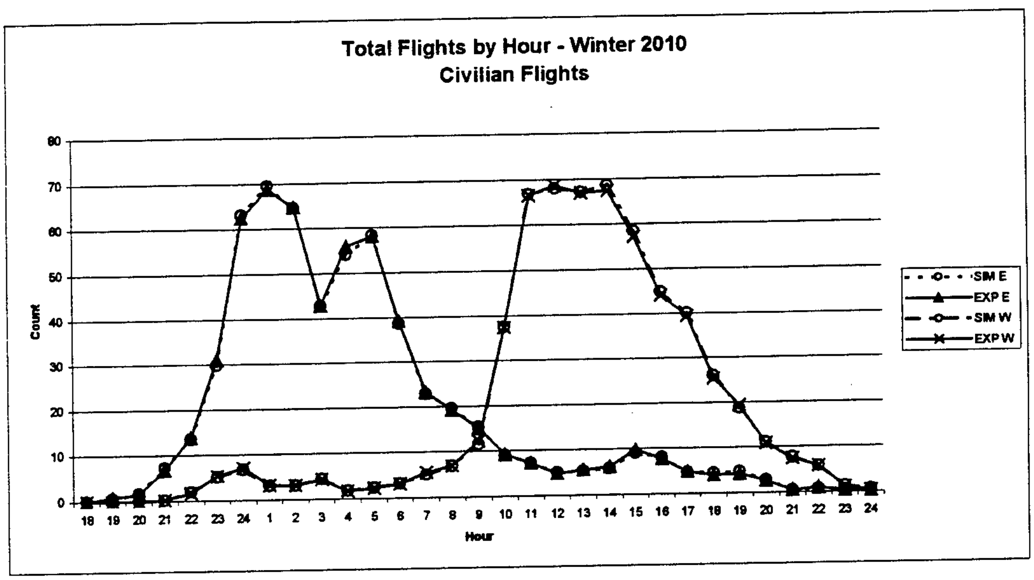
a. Year 1996



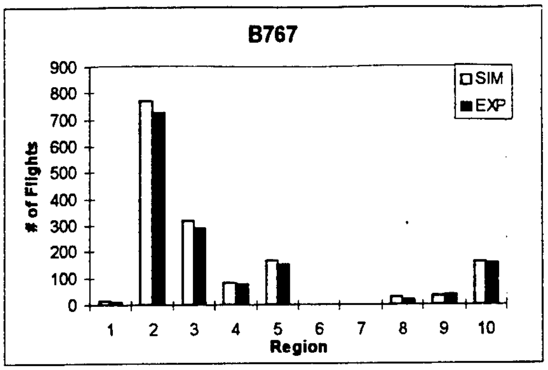


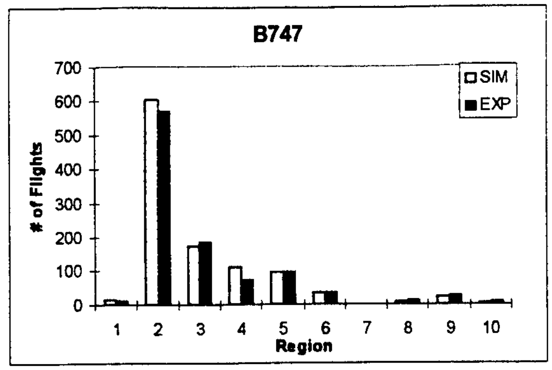
b. Year 2010

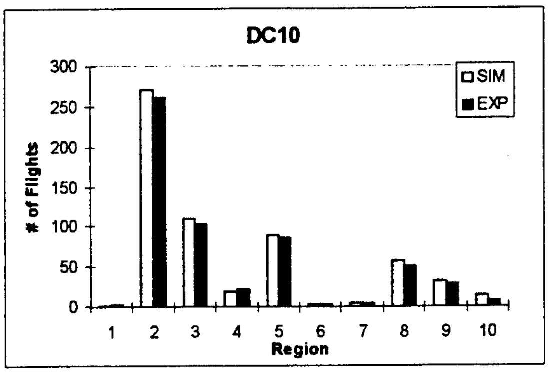

Total Flights by Hour - Summer 2010
Civilian Aircraft
Count
Hour
SIM E
EXP E
SIM W
EXP W

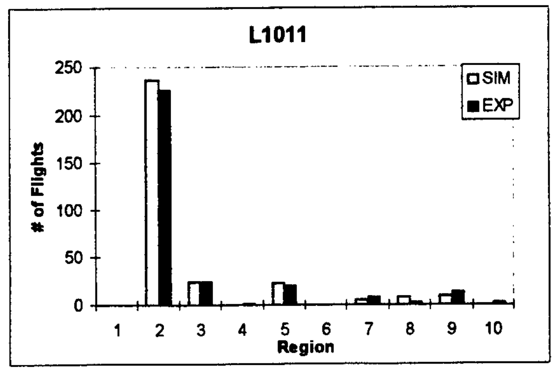

Total Flights by Hour - Winter 2010
Civilian Flights
Count
Hour
SIM E
EXP E
SIM W
EXP W

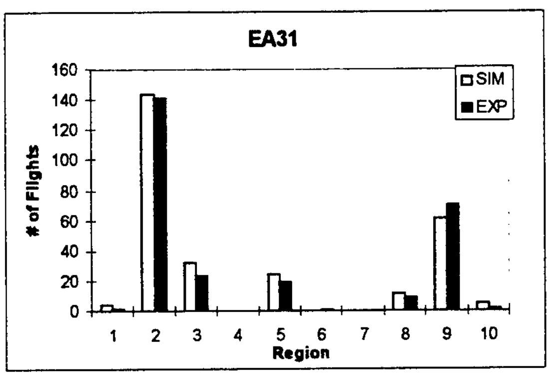
H2. AC Type, Summer, Eastbound, Year 1996

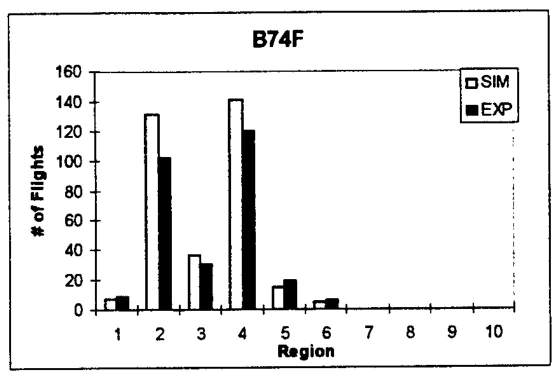


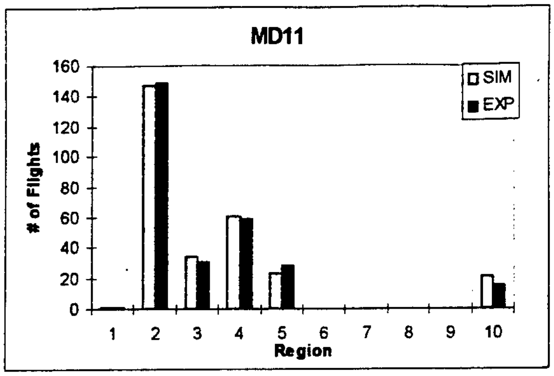


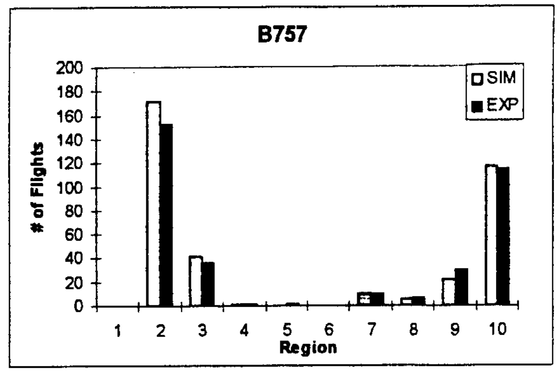


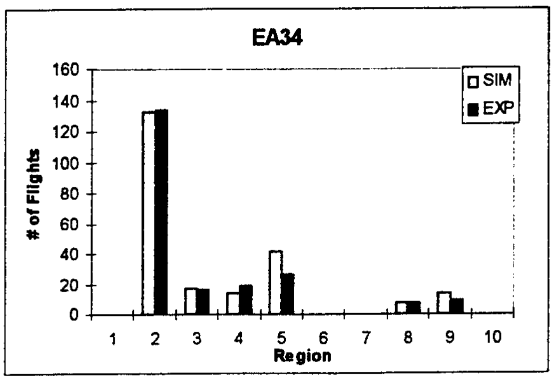


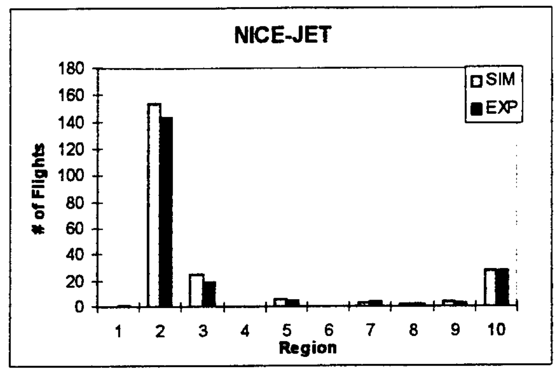


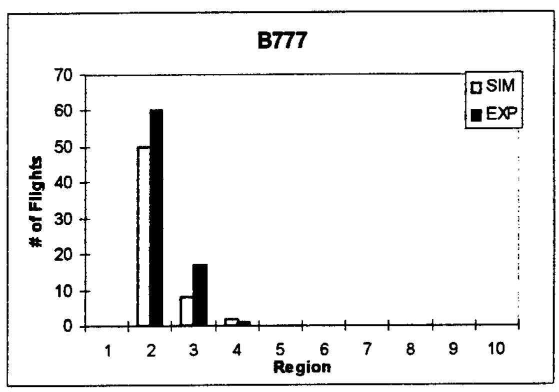



MD11
# of Flights
Region
SIM
EXP

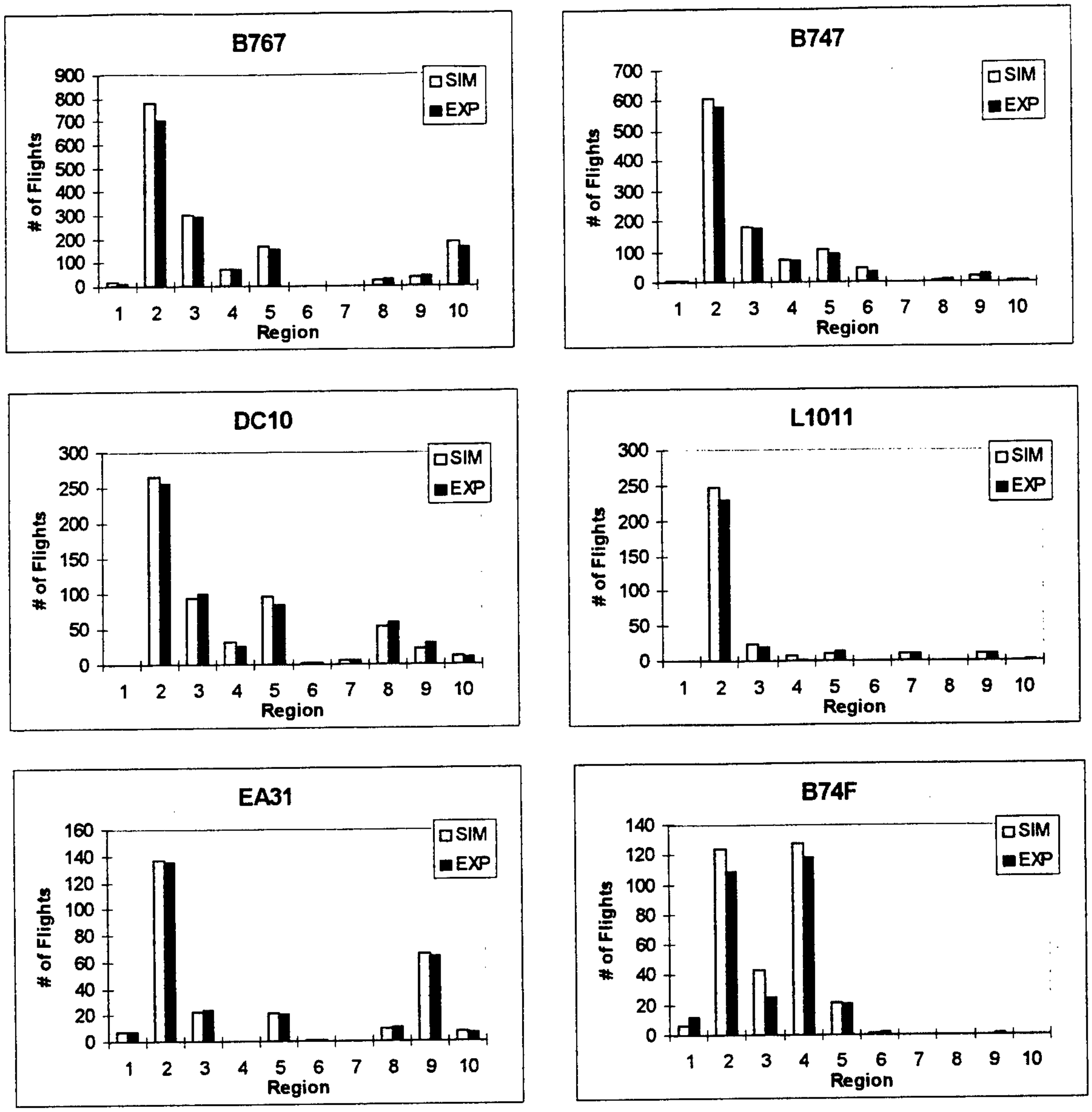

B757
# of Flights
Region
SIM
EXP

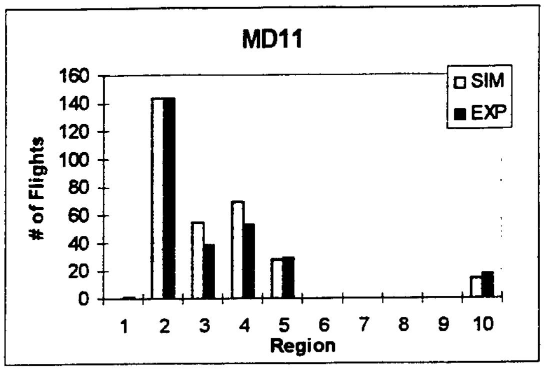

EA34
# of Flights
Region
SIM
EXP

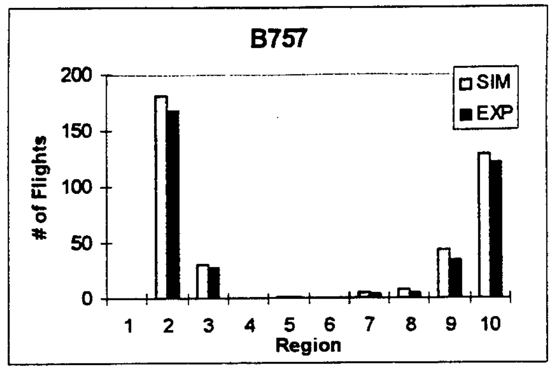

NICE-JET
# of Flights
Region
SIM
EXP

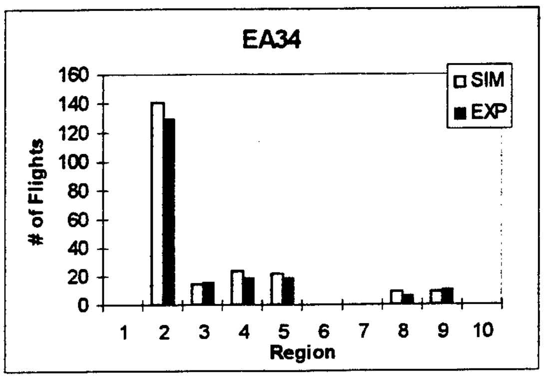

B777
# of Flights
Region
SIM
EXP

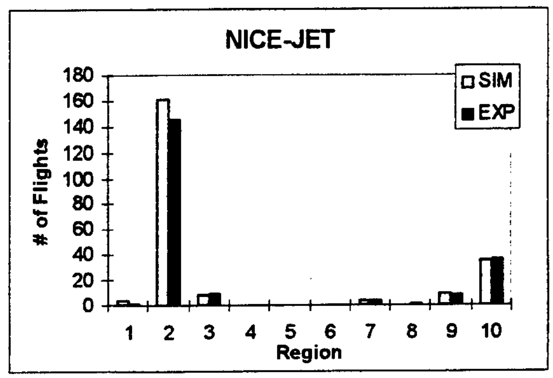
H3. AC Type, Summer, Westbound, Year 1996

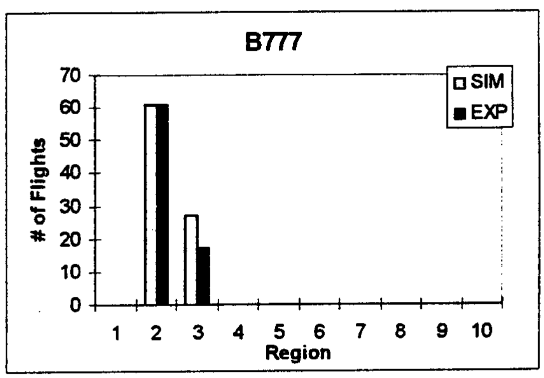



MD11
160
140
120
100
80
60
40
20
0
# of Flights
SIM
EXP
1 2 3 4 5 6 7 8 9 10
Region


B757
200
150
100
50
0
# of Flights
SIM
EXP
1 2 3 4 5 6 7 8 9 10
Region

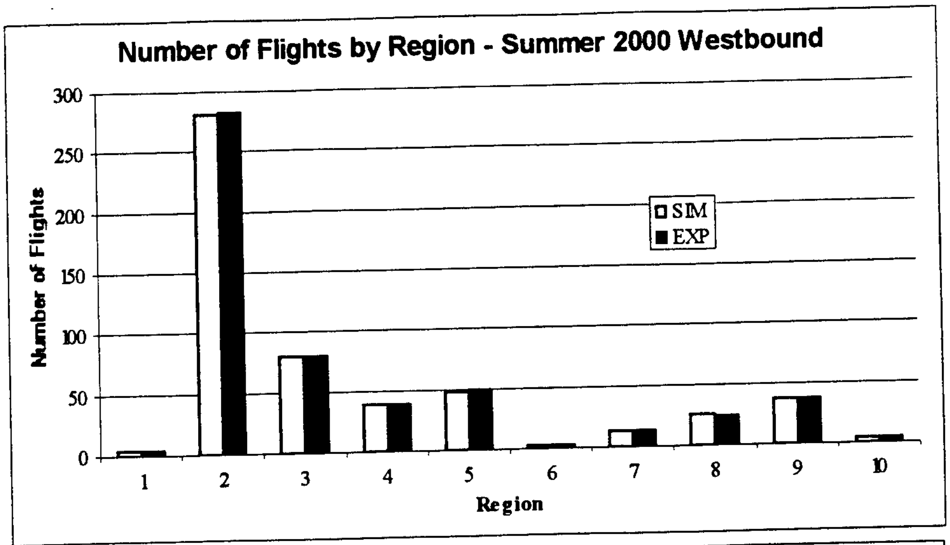

EA34
160
140
120
100
80
60
40
20
0
# of Flights
SIM
EXP
1 2 3 4 5 6 7 8 9 10
Region

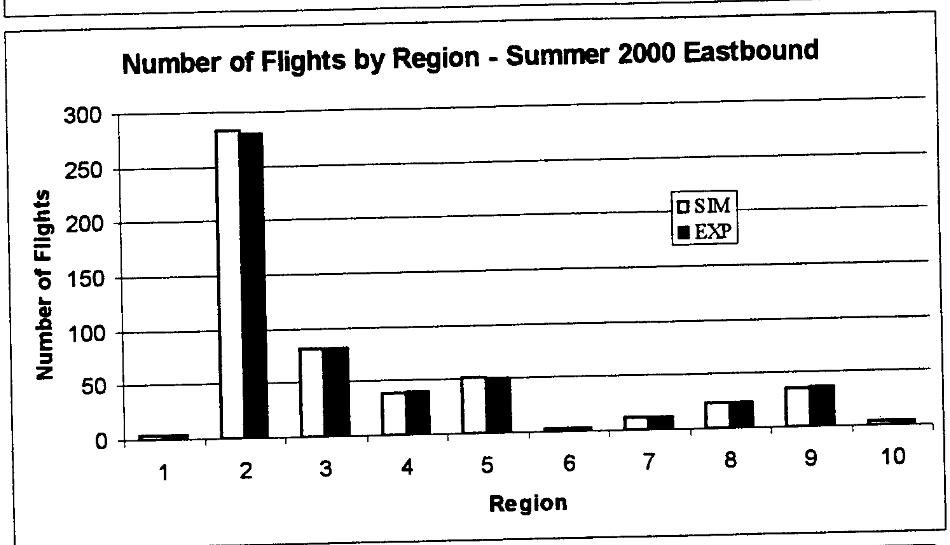

NICE-JET
180
160
140
120
100
80
60
40
20
0
# of Flights
SIM
EXP
1 2 3 4 5 6 7 8 9 10
Region

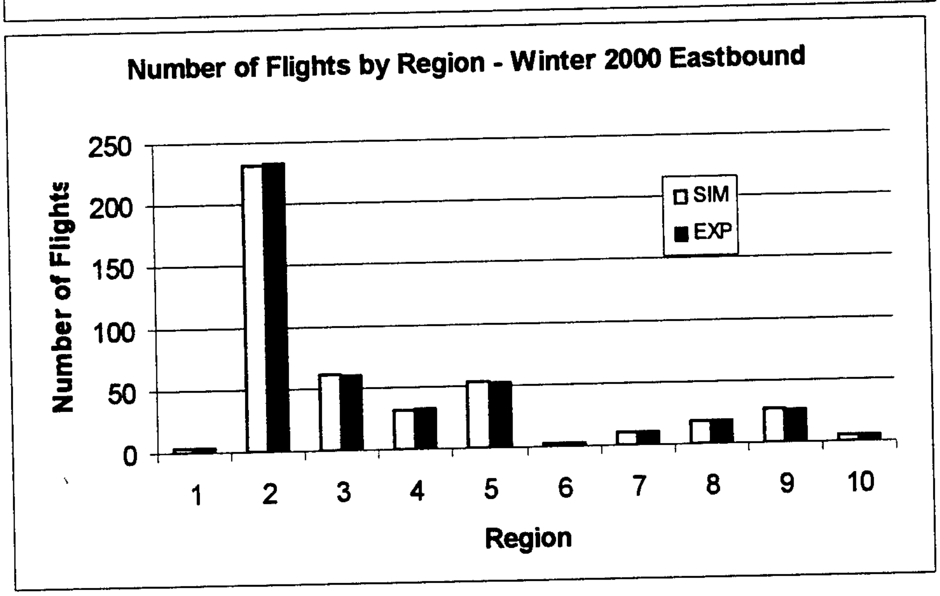

B777
70
60
50
40
30
20
10
0
# of Flights
SIM
EXP
1 2 3 4 5 6 7 8 9 10
Region

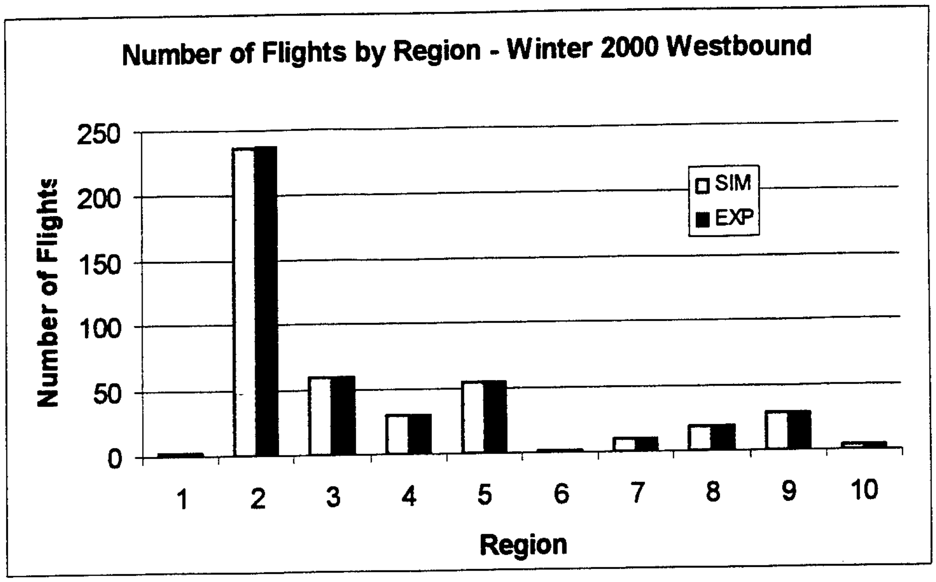
H4. Number of Aircraft By Region, Direction and Season

H5. Year 2000



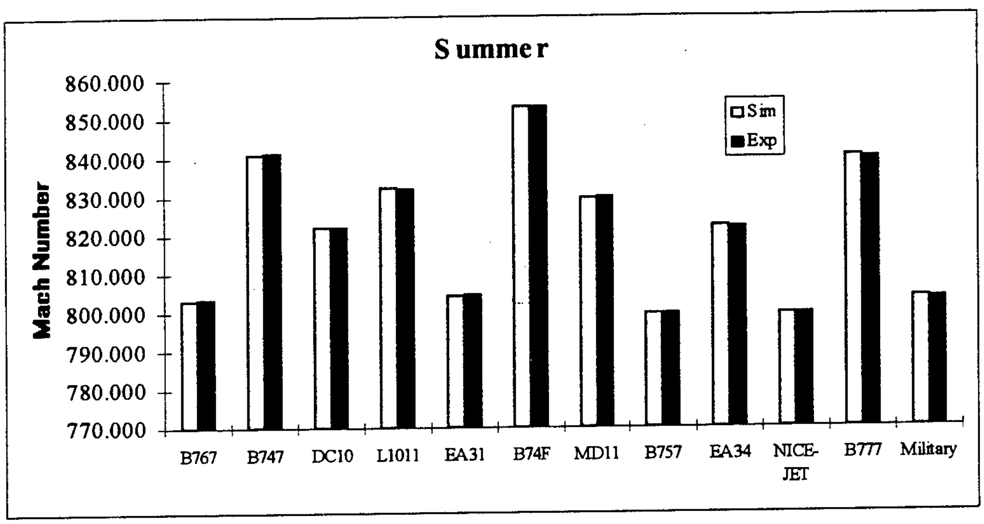


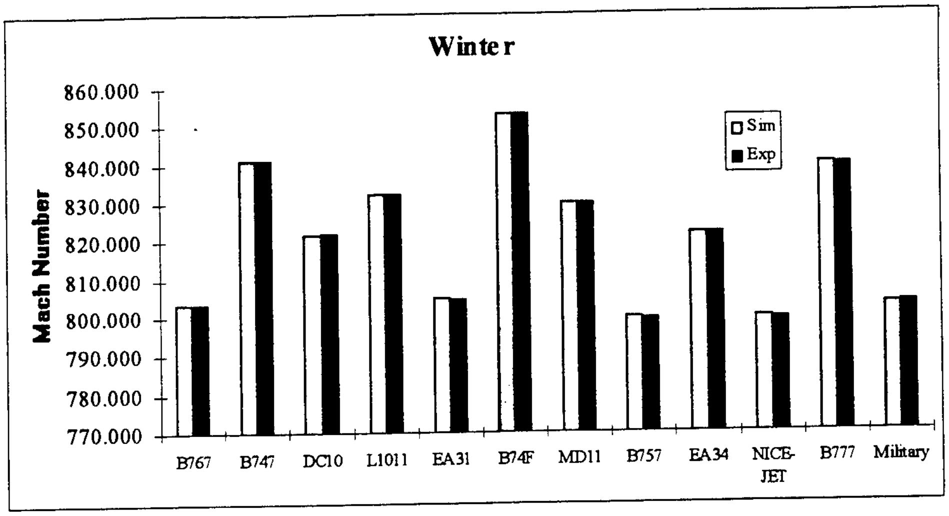




H6. Aircraft Mach Numbers by Season

H7. Year 1996




Winter
Mach Number
860.000
850.000
840.000
830.000
820.000
810.000
800.000
790.000
780.000
770.000
Sim
Exp
B767
B747
DC10
L1011
EA31
B74F
MD11
B757
EA34
NICE-JET
B777
Military

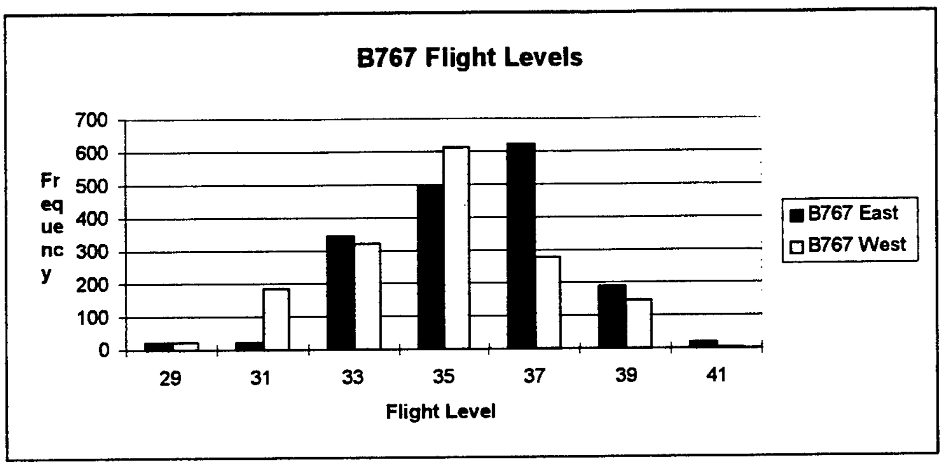
Appendix I

FPM Restrictions by Aircraft Type

I1. Source: Historical Gander OACC data, Jan - Aug. 1996 4th and 15th of the month, 15 days in total

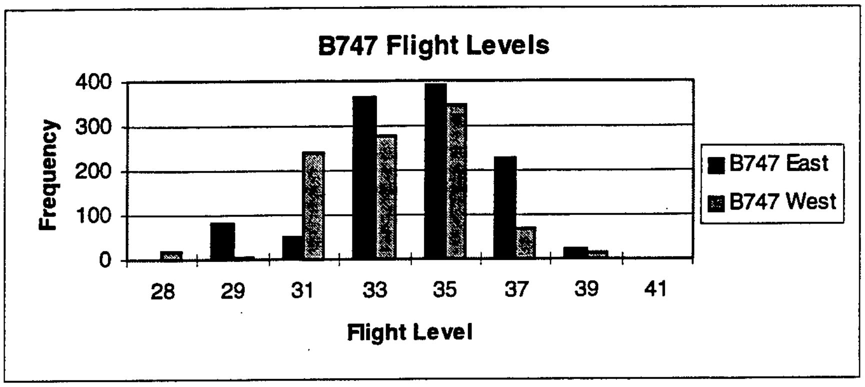
I2. B767

Flight Level	B767 East	B767 West
29	22	23
31	25	188
33	344	323
35	498	615
37	621	276
39	190	145
41	18	4
Totals	1718	1574



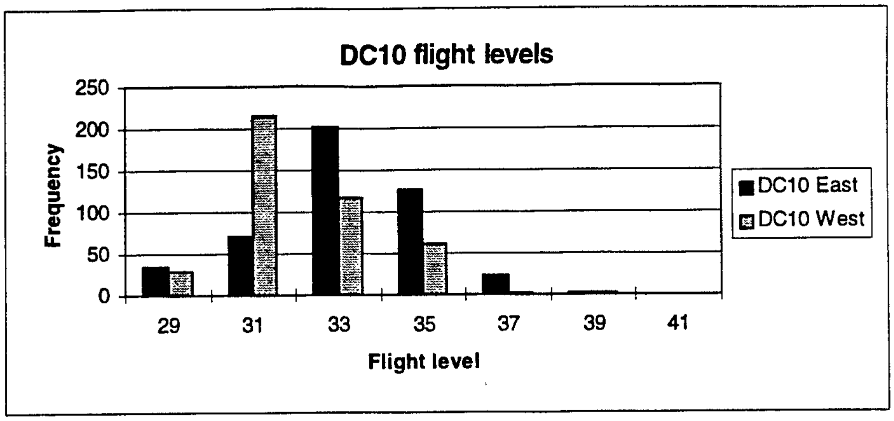
I1. B747

Flight Level	B747 East	B747 West
28	1	17
29	81	5
31	52	240
33	362	279
35	390	346
37	228	68
39	21	15
41	2	0
Totals	1137	970



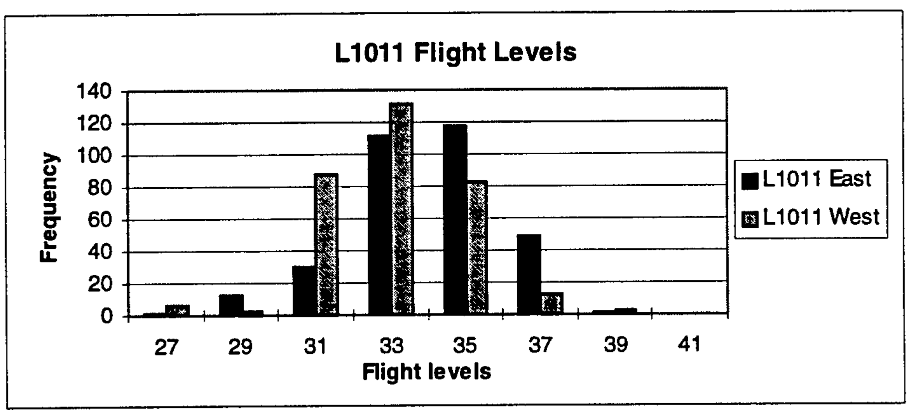
I1. DC10

Flight Level	DC10 East	DC10 West
29	35	28
31	71	215
33	201	117
35	126	62
37	23	2
39	1	2
41	0	0
Totals	457	426



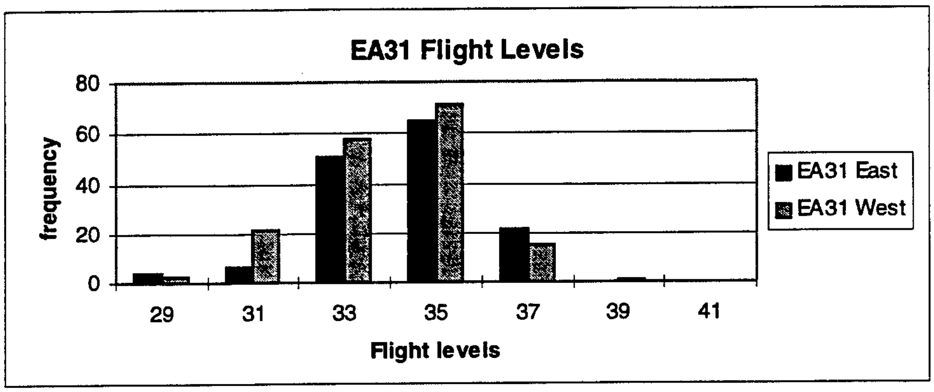
I1. L1011

Flight Level	L1011 East	L1011 West
27	1	6
29	12	2
31	30	88
33	111	131
35	118	83
37	49	12
39	1	2
41	0	0
Totals	322	324



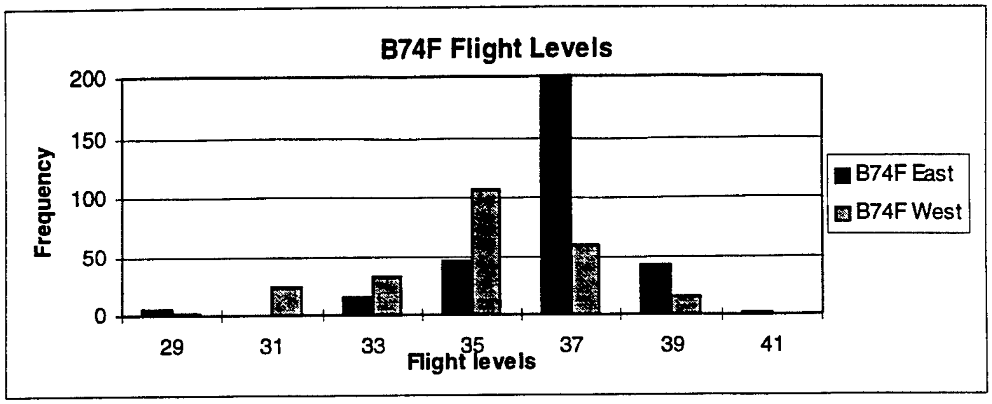
I1. EA31

Flight Level	EA31 East	EA31 West
29	4	2
31	6	21
33	51	58
35	65	71
37	21	15
39	0	1
41	0	0
Totals	147	168



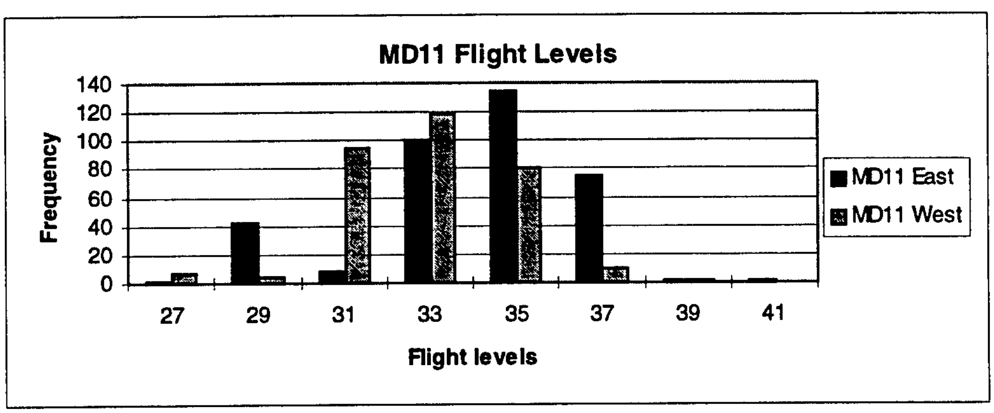
I1. B74F

Flight Level	B74F East	B74F West
29	5	2
31	0	23
33	15	33
35	46	106
37	200	60
39	43	16
41	1	0
Totals	310	240



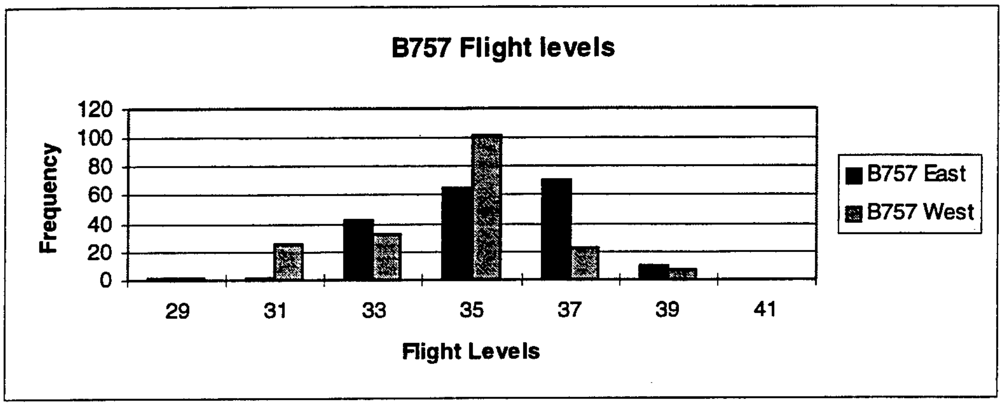
I1. MD11

Flight Level	MD11 East	MD11 West
27	2	7
29	43	4
31	8	95
33	100	119
35	135	81
37	75	10
39	1	2
41	1	0
Totals	365	318



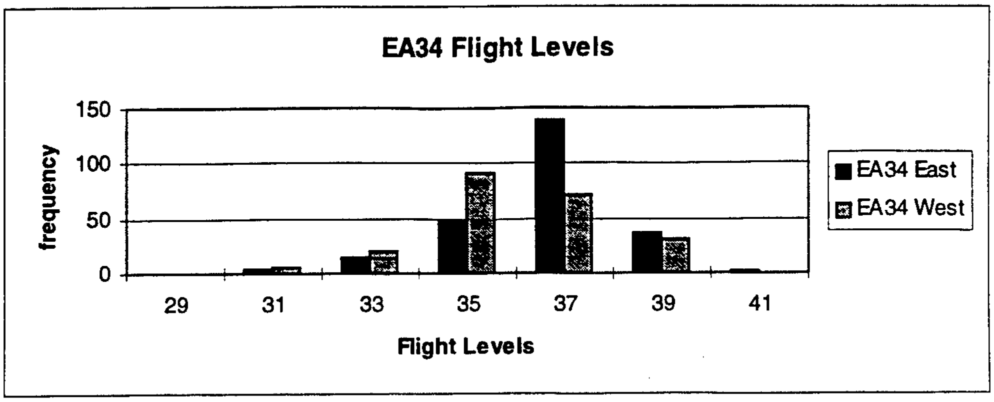
I1. B757

Flight Level	B757 East	B757 West
29	2	2
31	1	26
33	43	33
35	65	101
37	70	23
39	10	7
41	0	0
Totals	191	192



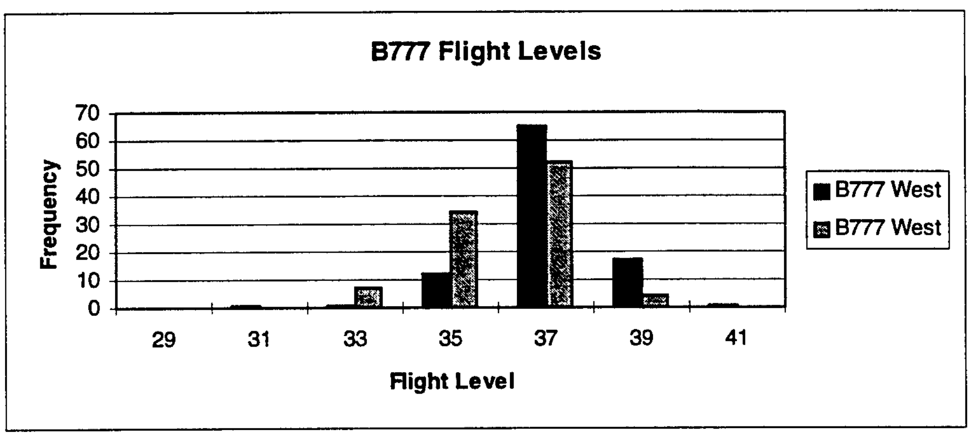
I1. EA34

Flight Level	EA34 East	EA34 West
29	0	0
31	4	6
33	14	21
35	48	92
37	139	72
39	37	31
41	1	0
Totals	243	222



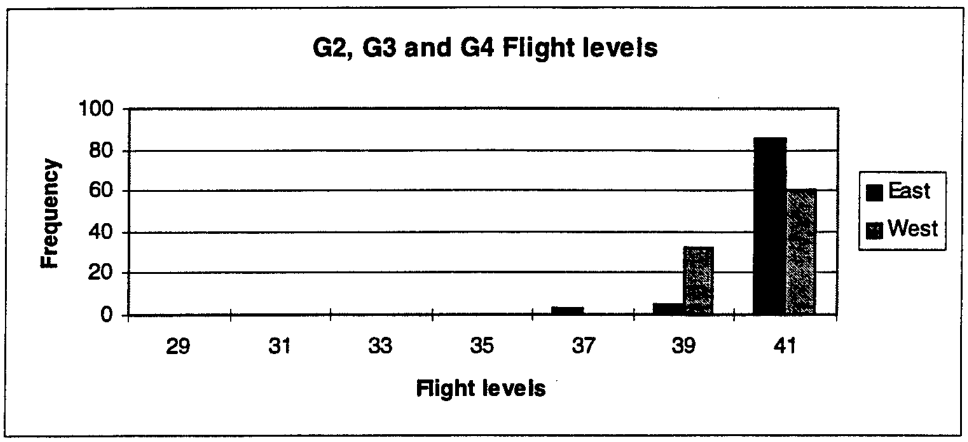
I1. B777

Flight Level	B777 West	B777 West
29	0	0
31	1	0
33	1	7
35	12	34
37	65	52
39	17	4
41	1	0
Totals	97	97



I1. Misc Jets: G2, G3, G4 (NICE-JET)

Flight Level	**East**	**West**
29	0	0
31	0	0
33	0	0
35	0	0
37	3	0
39	5	32
41	85	60
Totals	93	92



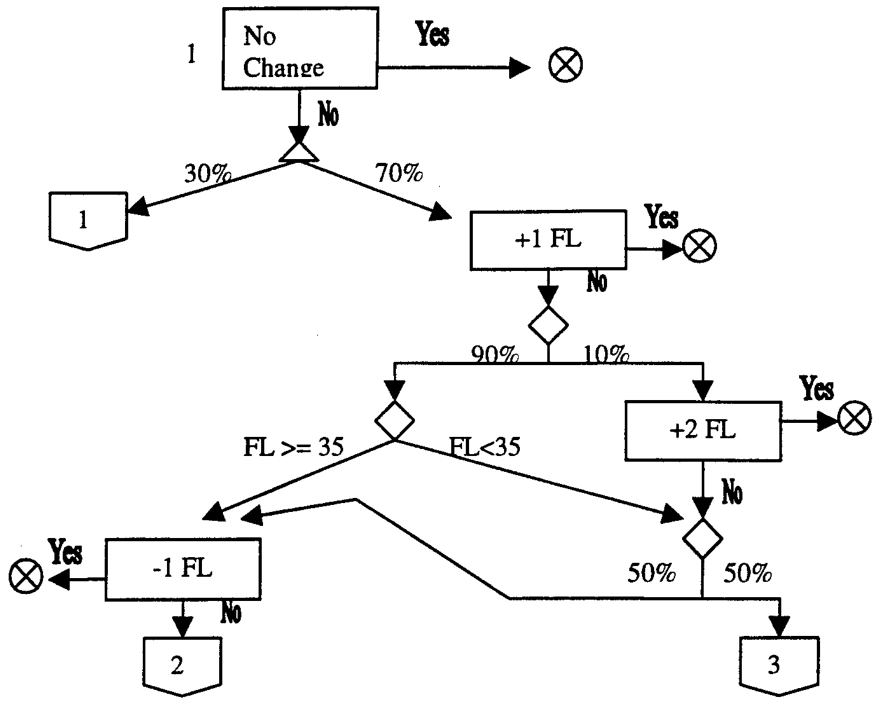
Appendix J

NICE-USA Re-clearance Logic

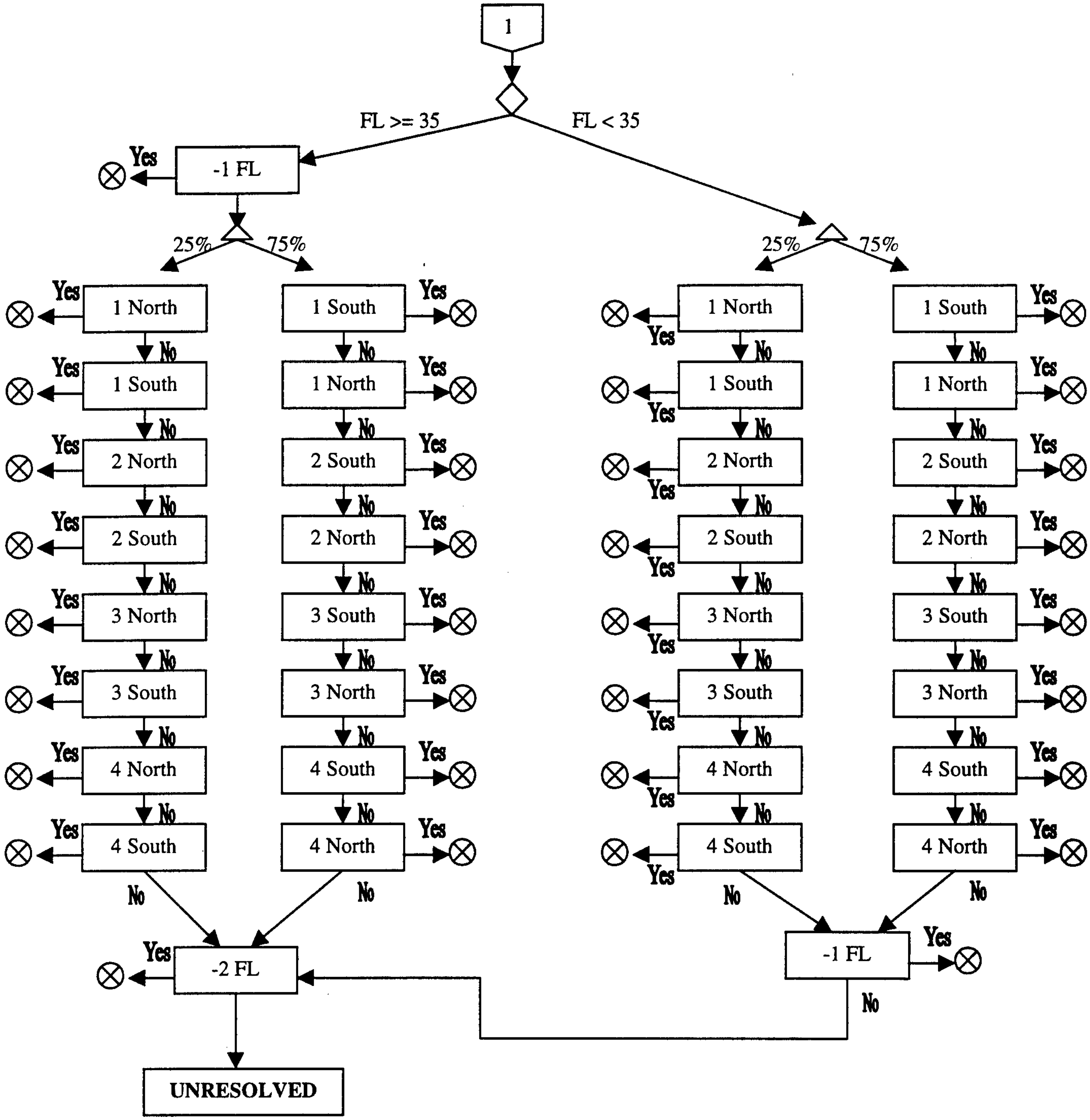
J1. There are four separated rerouting decision trees used in the NICE-USA model. The re-clearance logic for the following directions and scenarios are presented in this Appendix.

a. Eastbound, Baseline, RVSM and RVLSM
b. Eastbound, RVHSM
c. Westbound, Baseline, RVSM and RVLSM
d. Westbound, RVHSM

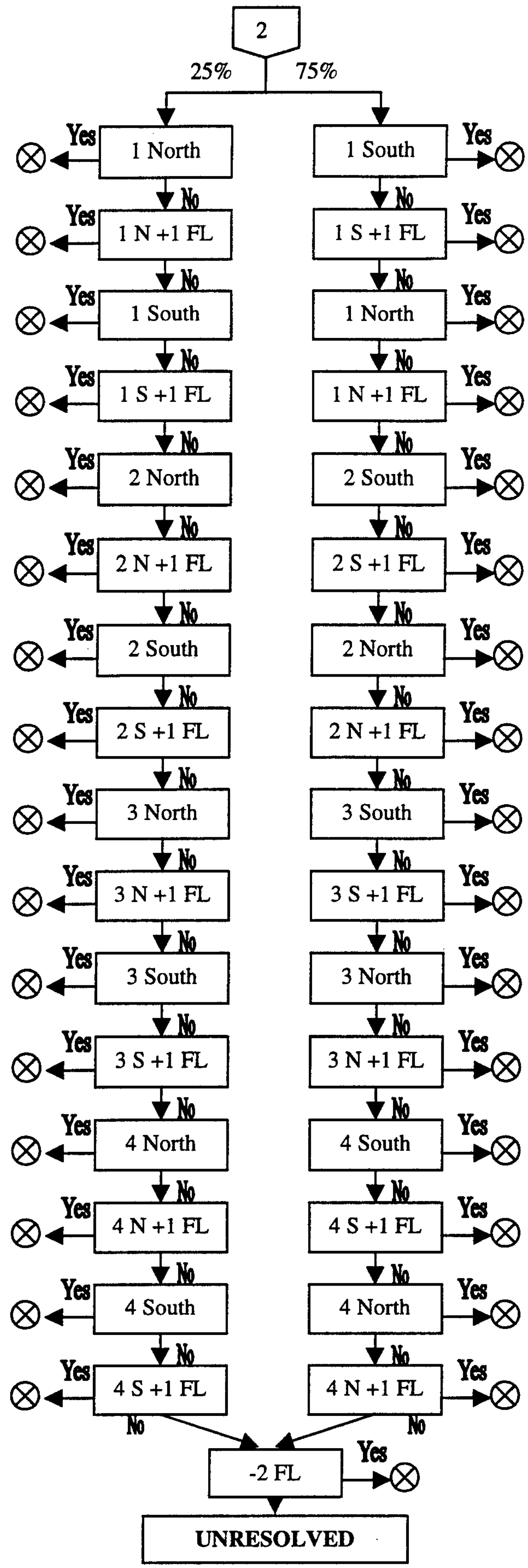
J2. Eastbound CS, RVSM, RVLSM Re-clearance Logic



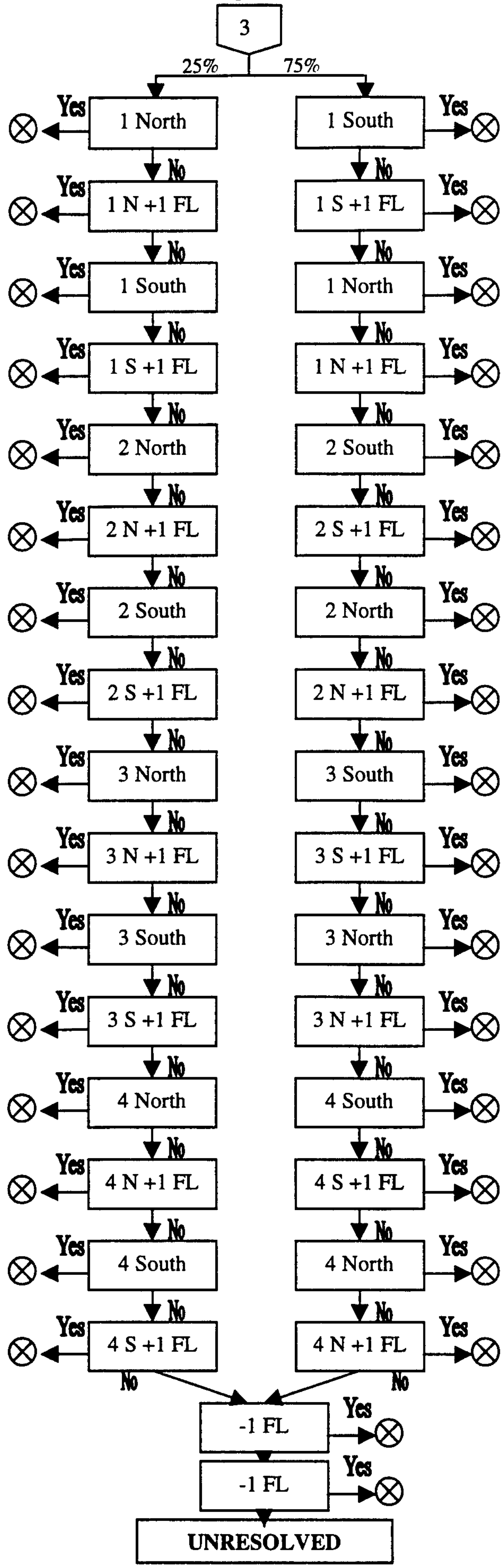
J3. Eastbound CS, RVSM, RVLSM Re-clearance Logic (con't)



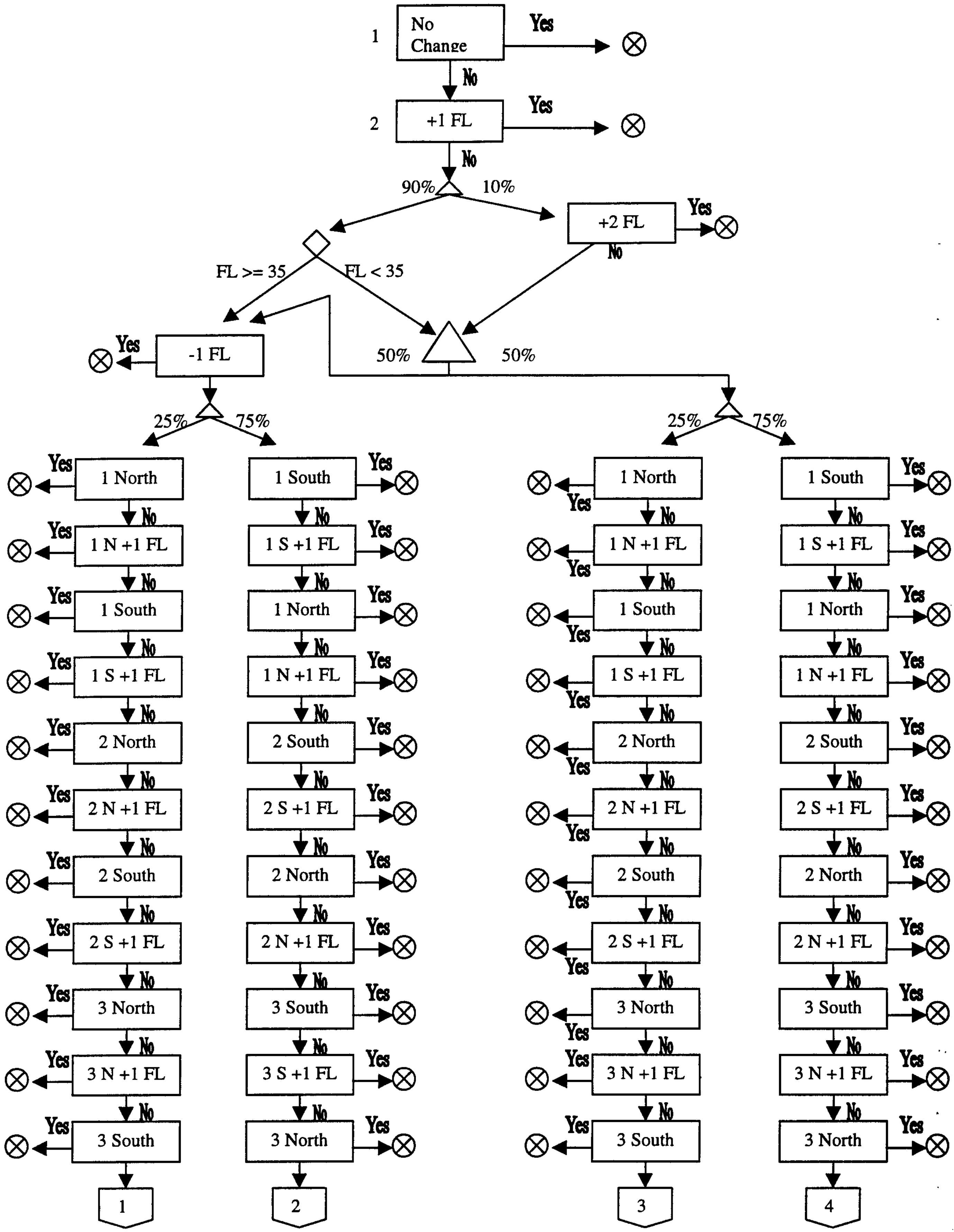
J4. Eastbound CS, RVSM, RVLSM Re-clearance Logic (con't)



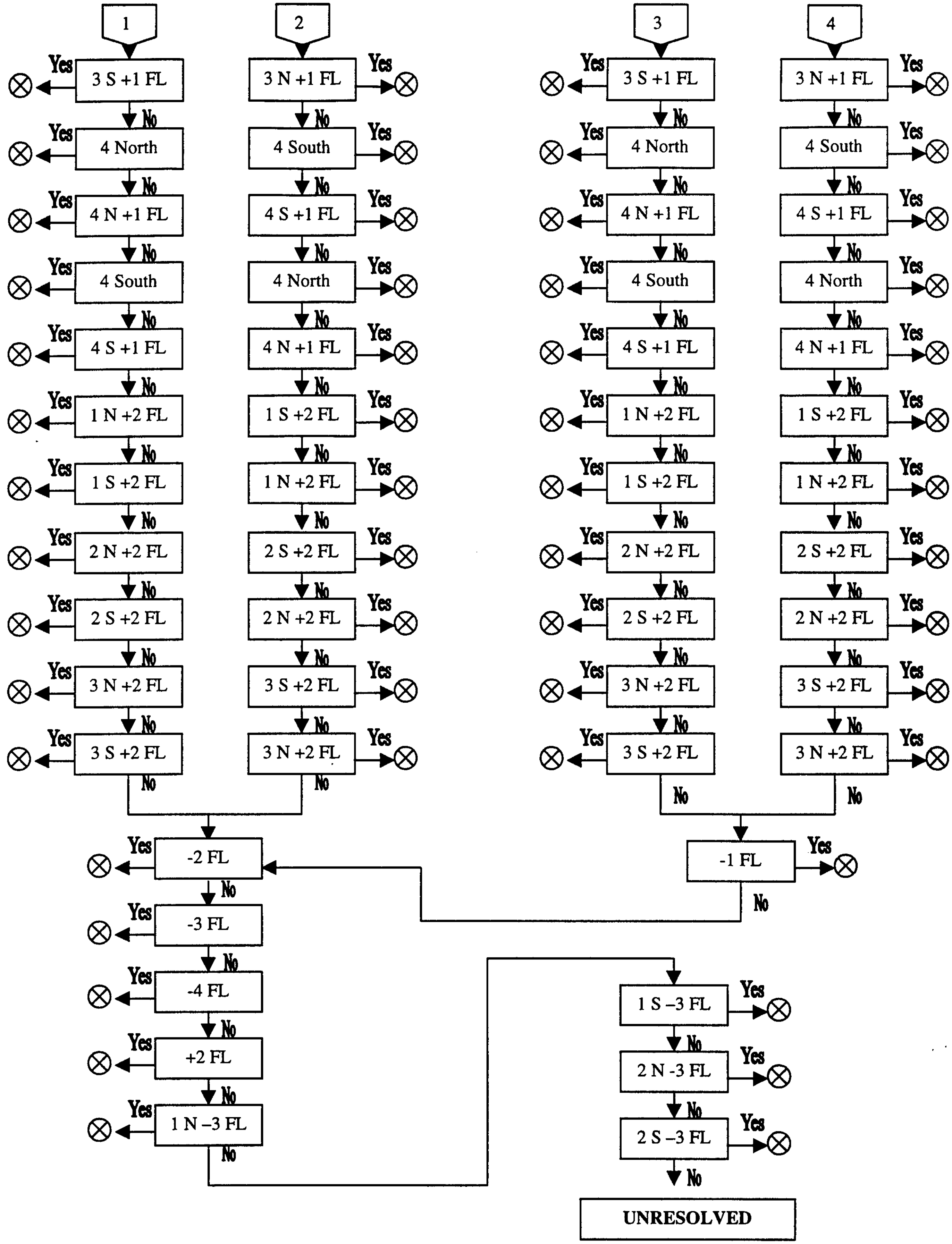
J5. Eastbound CS, RVSM, RVLSM Re-clearance Logic (con't)



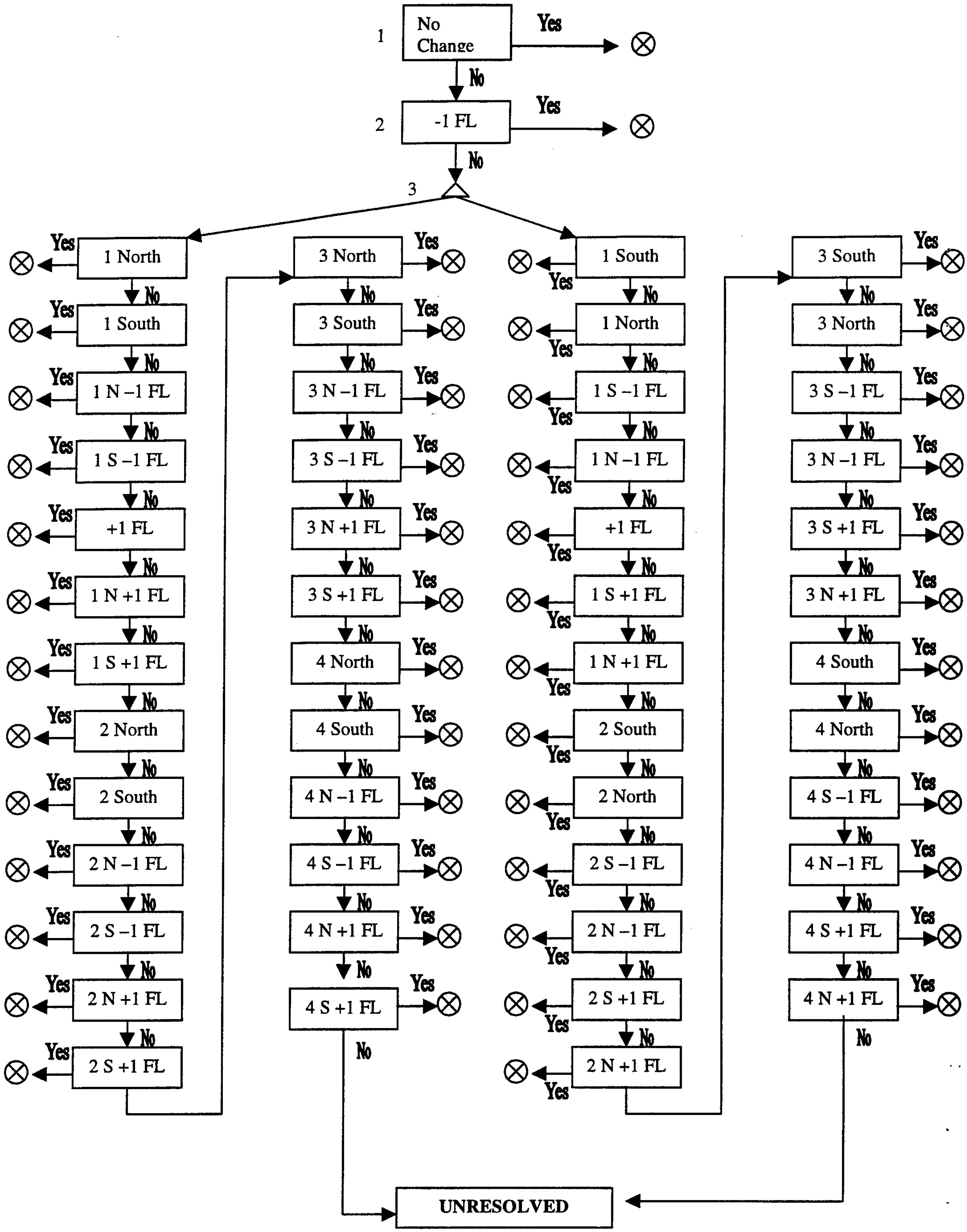
J6. Eastbound RVHSM Re-clearance Logic



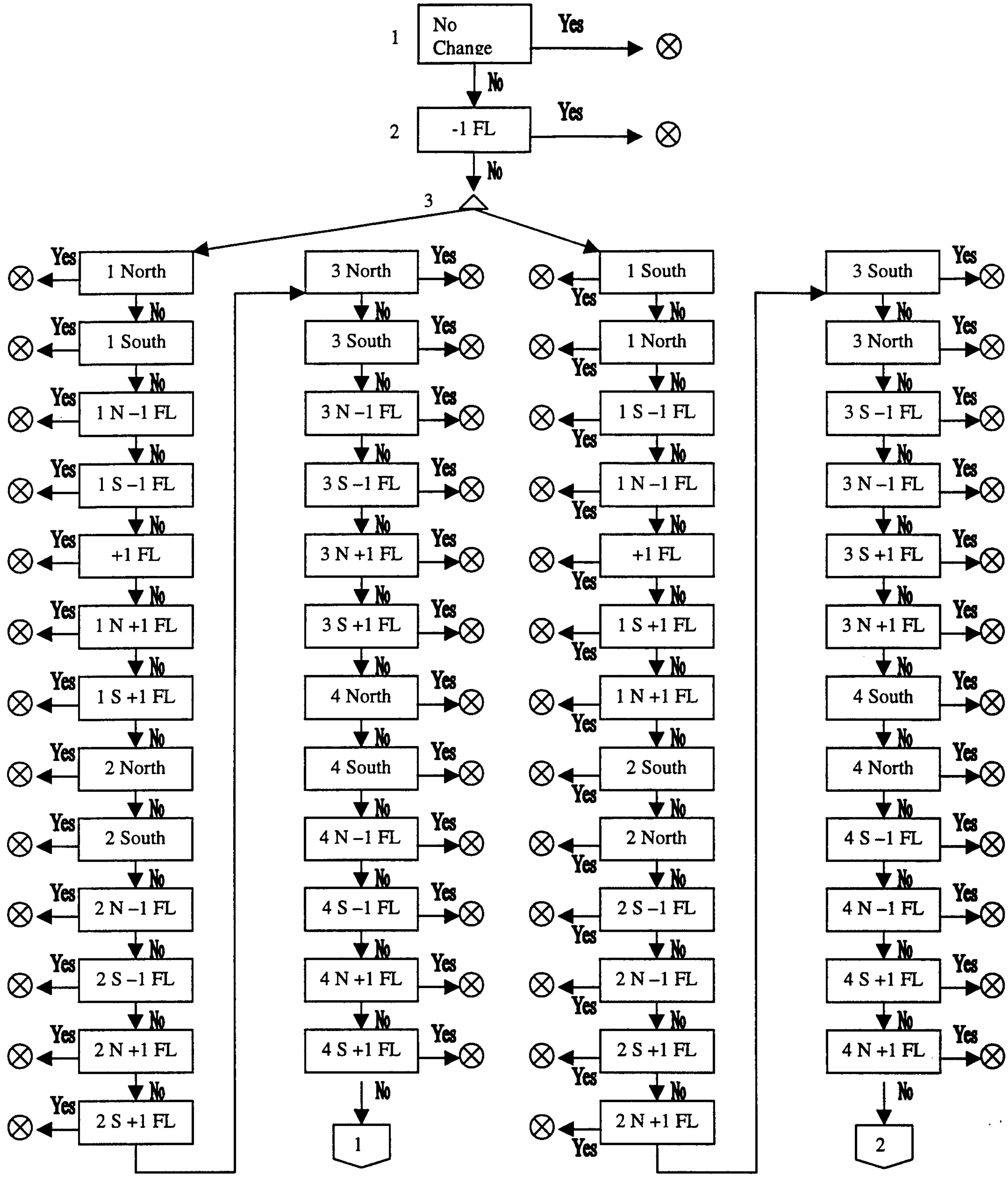
J7. Eastbound RVHSM Re-clearance Logic (con't)



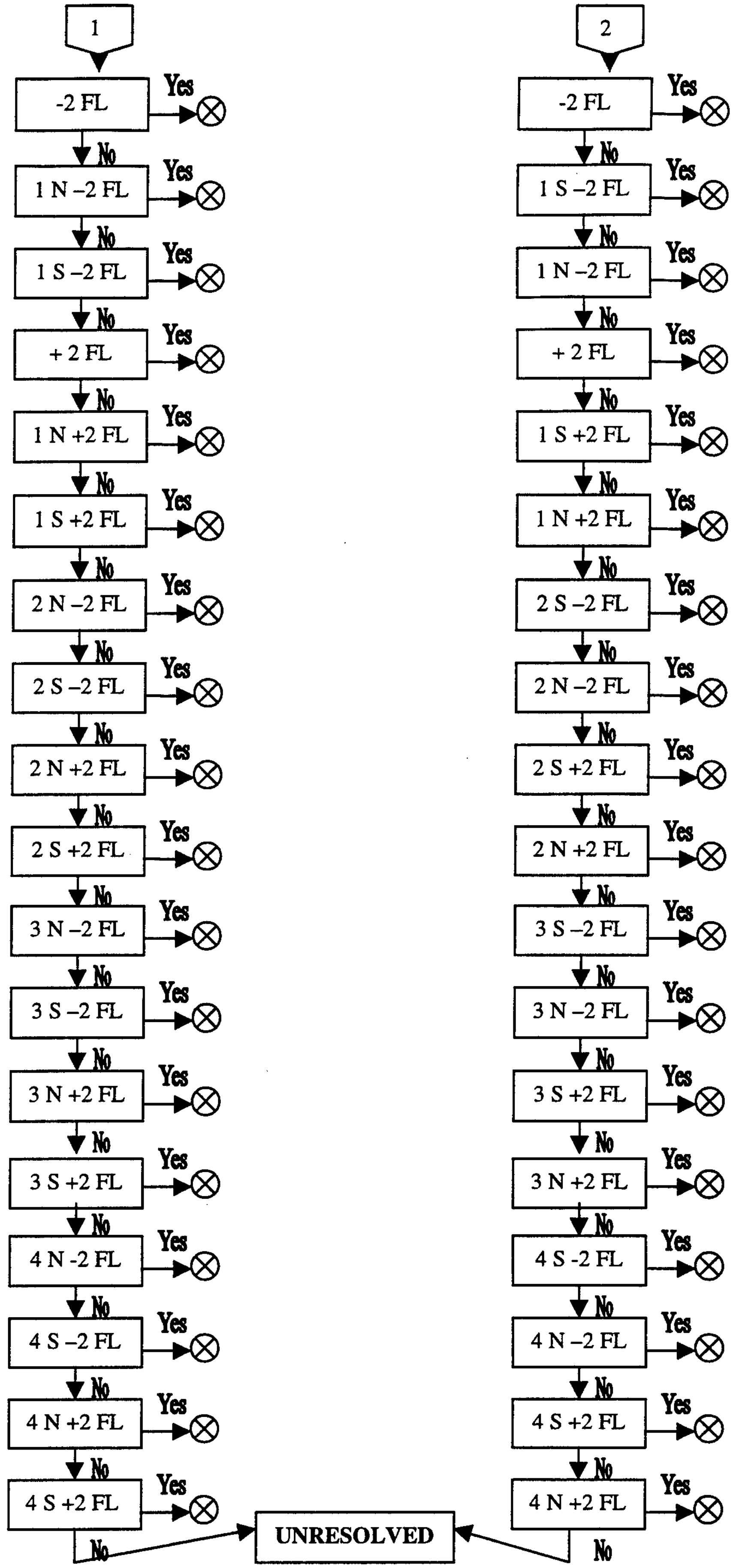
J8. Westbound CS, RVSM, RVLSM Re-clearance Logic



J9. Westbound RVHSM Re-clearance Logic



J10. Westbound RVHSM Re-clearance Logic (con't)



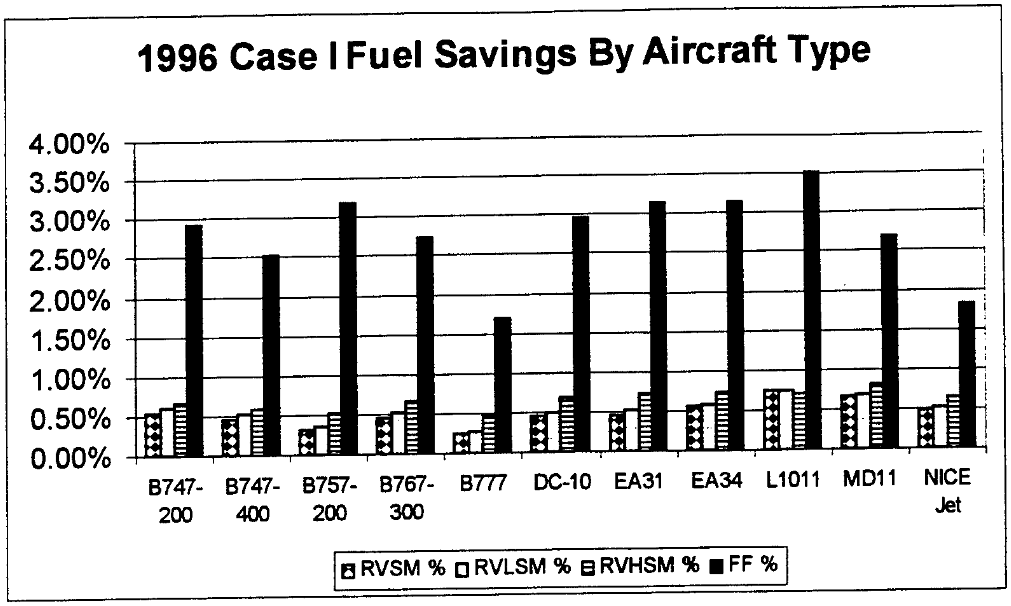
Appendix K

Complete Analysis of Case I Fuel Burn

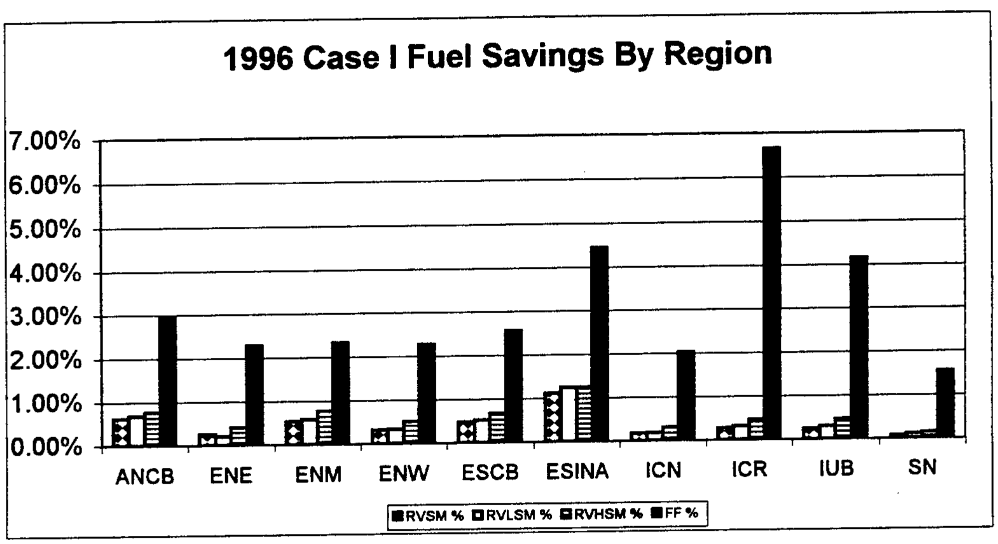
K1. 1996 Case I Fuel Results: Computed as 100% * (Baseline – Scenario / Scenario.

Day	RVSM %	RVLSM %	RVHSM %	FF %
Jan 4	0.81%	0.85%	0.92%	3.11%
Jan 15	0.83%	0.93%	1.03%	3.20%
Feb 4	0.36%	0.39%	0.65%	2.23%
Feb 15	0.38%	0.41%	0.49%	2.28%
Mar 4	0.33%	0.38%	0.54%	2.40%
Mar 15	0.39%	0.43%	0.55%	2.51%
Apr 4	0.30%	0.32%	0.51%	2.68%
Apr 15	0.42%	0.44%	0.54%	2.51%
May 4	0.46%	0.49%	0.66%	2.38%
May 15	0.36%	0.44%	0.65%	2.50%
Jun 4	0.43%	0.51%	0.68%	2.33%
Jun 15	0.60%	0.59%	0.75%	2.74%
Jul 4	0.48%	0.54%	0.75%	2.41%
Jul 15	0.43%	0.46%	0.42%	2.58%
Aug 4	1.03%	1.18%	1.16%	3.27%
Aug 15	0.65%	0.69%	0.96%	2.72%
Sep 4	1.24%	1.27%	1.36%	3.97%
Sep 15	0.36%	0.41%	0.57%	2.49%
Oct 4	0.42%	0.42%	0.53%	2.18%
Oct 15	0.65%	0.71%	0.79%	2.80%
Nov 4	0.16%	0.21%	0.52%	2.74%
Nov 15	0.76%	0.81%	1.01%	2.75%
Dec 4	0.36%	0.37%	0.39%	2.38%
Dec 15	0.63%	0.68%	0.75%	2.66%

a. Case I Fuel Savings by Aircraft Type for Year 1996



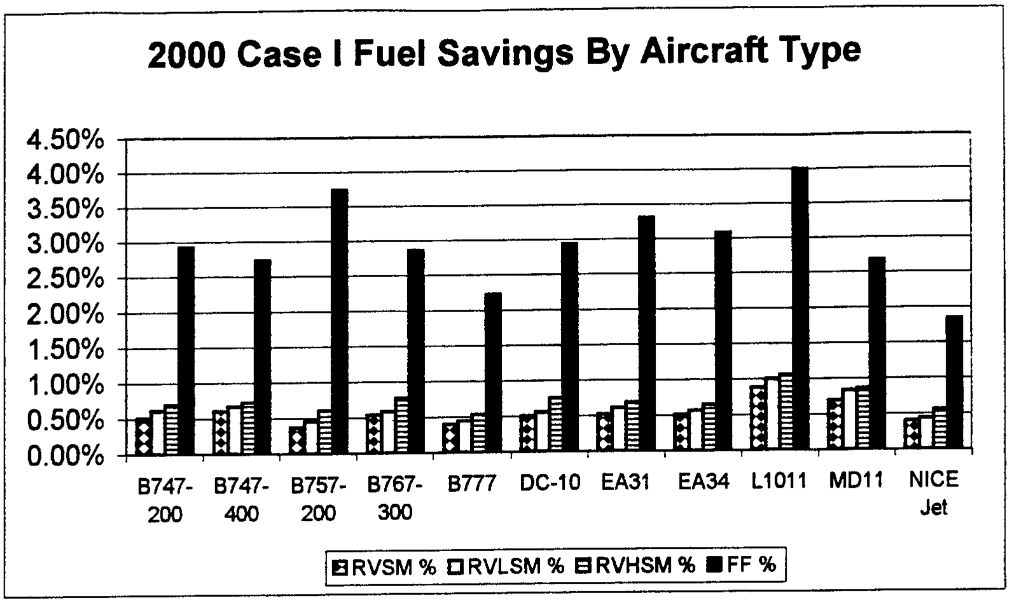
b. Case I Fuel Savings by Flight Regions for Year 1996



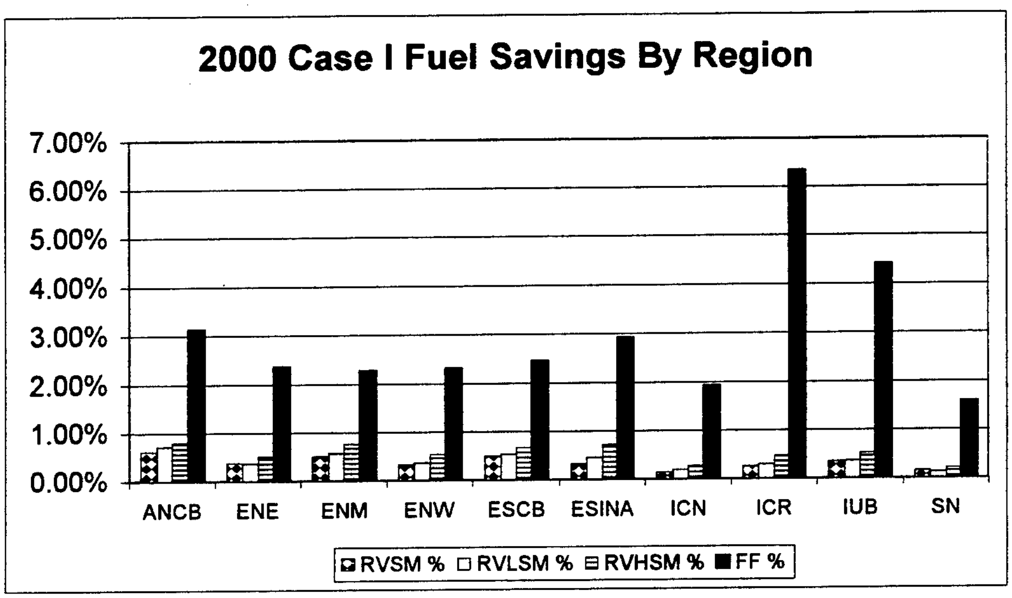
K2. 2000 Case I Fuel Results: Computed as 100% * (Baseline – Scenario / Scenario.

Day	RVSM %	RVLSM %	RVHSM %	FF %
Jan 4	0.78%	0.82%	1.03%	2.97%
Jan 15	0.76%	0.84%	0.98%	3.00%
Feb 4	0.42%	0.54%	0.75%	2.30%
Feb 15	0.36%	0.36%	0.51%	2.37%
Mar 4	0.25%	0.36%	0.64%	2.40%
Mar 15	0.34%	0.41%	0.46%	2.47%
Apr 4	0.46%	0.42%	0.48%	2.71%
Apr 15	0.38%	0.46%	0.60%	2.53%
May 4	0.63%	0.68%	0.74%	2.57%
May 15	0.57%	0.65%	0.85%	2.67%
Jun 4	0.43%	0.47%	0.61%	2.30%
Jun 15	0.69%	0.78%	0.80%	2.85%
Jul 4	0.47%	0.59%	0.74%	2.43%
Jul 15	0.56%	0.63%	0.73%	2.65%
Aug 4	0.91%	1.10%	1.10%	3.08%
Aug 15	0.56%	0.62%	0.88%	2.58%
Sep 4	0.83%	0.94%	1.01%	3.57%
Sep 15	0.32%	0.33%	0.46%	2.36%
Oct 4	0.60%	0.65%	0.69%	2.54%
Oct 15	0.74%	0.77%	0.94%	2.81%
Nov 4	0.37%	0.47%	0.84%	2.84%
Nov 15	0.96%	1.02%	1.15%	2.94%
Dec 4	0.51%	0.54%	0.60%	2.57%
Dec 15	0.70%	0.77%	0.80%	2.64%

a. Case I Fuel Savings by Aircraft Type for Year 2000



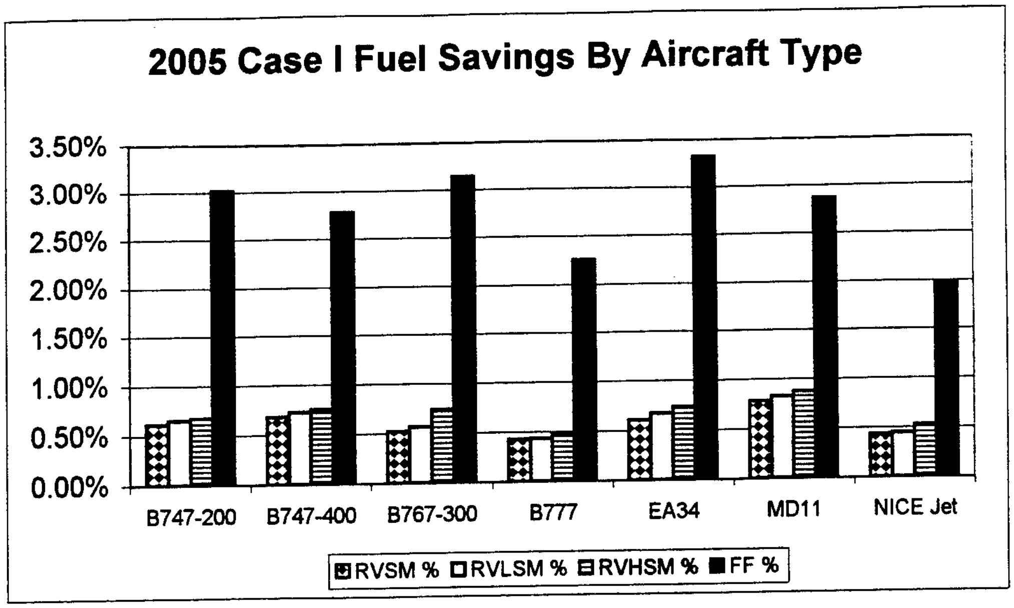
b. Case I Fuel Savings by Flight Regions for Year 2000



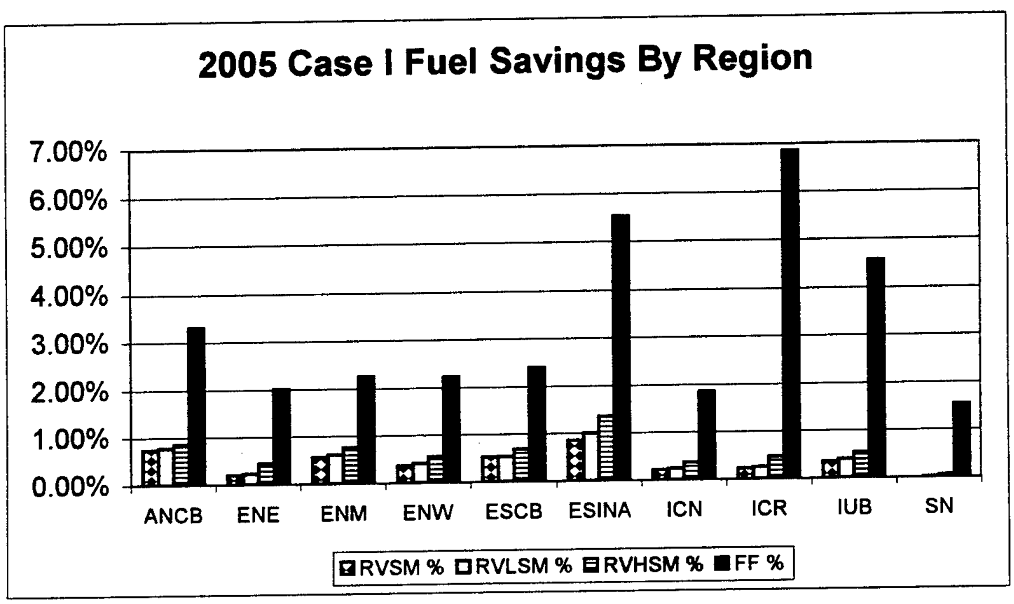
K3. 2005 Case I Fuel Results: Computed as 100% * (Baseline – Scenario / Scenario.

Day	RVSM %	RVLSM %	RVHSM %	FF %
Jan 4	0.78%	0.78%	0.91%	2.93%
Jan 15	0.60%	0.65%	0.72%	2.92%
Feb 4	0.46%	0.51%	0.77%	2.33%
Feb 15	0.46%	0.51%	0.52%	2.45%
Mar 4	0.29%	0.29%	0.45%	2.33%
Mar 15	0.51%	0.56%	0.67%	2.64%
Apr 4	0.53%	0.58%	0.62%	2.71%
Apr 15	0.41%	0.44%	0.55%	2.44%
May 4	0.71%	0.74%	0.88%	2.61%
May 15	0.55%	0.52%	0.66%	2.48%
Jun 4	0.97%	0.96%	1.21%	2.82%
Jun 15	0.58%	0.65%	0.65%	2.69%
Jul 4	0.49%	0.52%	0.72%	2.35%
Jul 15	0.70%	0.82%	0.84%	2.83%
Aug 4	1.02%	1.12%	1.16%	3.05%
Aug 15	0.71%	0.78%	1.00%	2.69%
Sep 4	1.12%	1.19%	1.23%	3.74%
Sep 15	0.40%	0.43%	0.59%	2.44%
Oct 4	0.59%	0.59%	0.64%	2.24%
Oct 15	0.64%	0.64%	0.75%	2.56%
Nov 4	0.26%	0.34%	0.66%	2.76%
Nov 15	0.80%	0.83%	0.98%	2.75%
Dec 4	0.58%	0.61%	0.60%	2.65%
Dec 15	0.59%	0.67%	0.69%	2.48%

a. Case I Fuel Savings by Aircraft Type for Year 2005



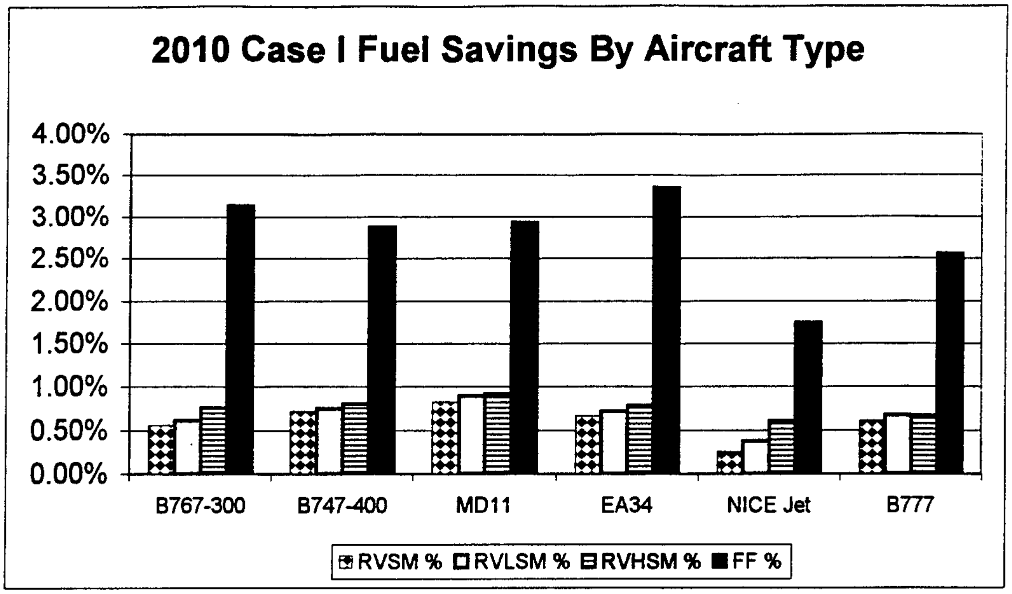
b. Case I Fuel Savings by Flight Regions for Year 2005



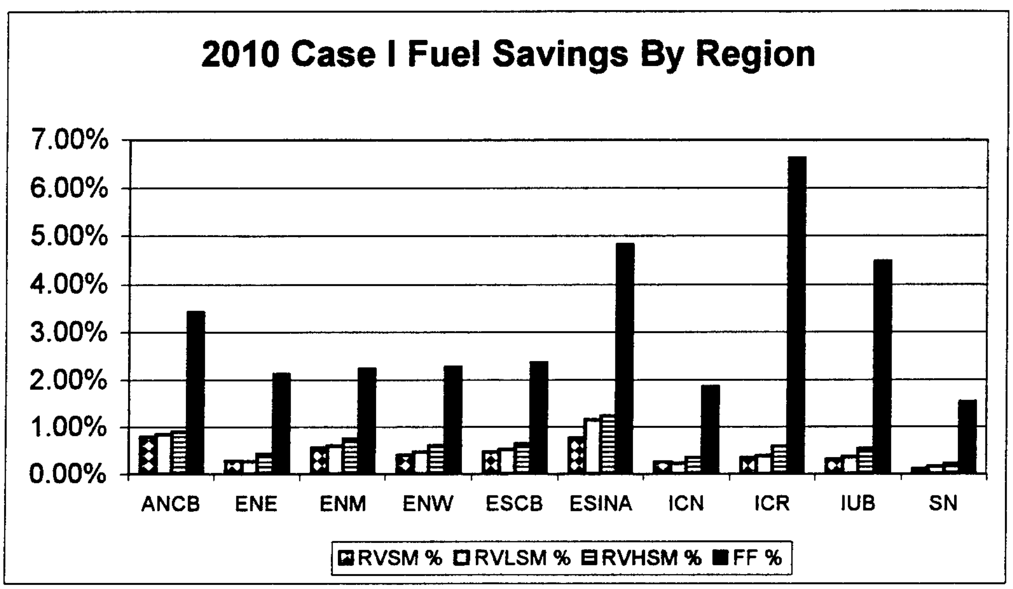
K4. 2010 Case I Fuel Results: Computed as 100% * (Baseline – Scenario / Scenario.

Day	RVSM %	RVLSM %	RVHSM %	FF %
Jan 4	0.71%	0.74%	0.95%	2.98%
Jan 15	0.76%	0.82%	0.65%	3.01%
Feb 4	0.54%	0.61%	0.79%	2.36%
Feb 15	0.30%	0.34%	0.45%	2.28%
Mar 4	0.49%	0.49%	0.55%	2.40%
Mar 15	0.51%	0.53%	0.65%	2.66%
Apr 4	0.53%	0.54%	0.65%	2.64%
Apr 15	0.58%	0.61%	0.80%	2.65%
May 4	0.81%	0.87%	0.93%	2.67%
May 15	0.67%	0.73%	0.86%	2.60%
Jun 4	1.25%	1.33%	1.48%	3.11%
Jun 15	0.74%	0.79%	0.78%	2.93%
Jul 4	0.63%	0.69%	0.84%	2.44%
Jul 15	0.68%	0.75%	0.78%	2.84%
Aug 4	0.92%	1.08%	1.09%	2.90%
Aug 15	0.56%	0.57%	0.77%	2.53%
Sep 4	1.32%	1.38%	1.43%	4.01%
Sep 15	0.41%	0.45%	0.62%	2.40%
Oct 4	0.77%	0.82%	0.72%	2.54%
Oct 15	0.61%	0.65%	0.80%	2.64%
Nov 4	0.38%	0.46%	0.77%	2.81%
Nov 15	0.76%	0.83%	0.92%	2.57%
Dec 4	0.65%	0.70%	0.69%	2.63%
Dec 15	0.80%	0.82%	0.85%	2.74%

a. Case I Fuel Savings by Aircraft Type for Year 2010



b. Case I Fuel Savings by Flight Regions for Year 2010



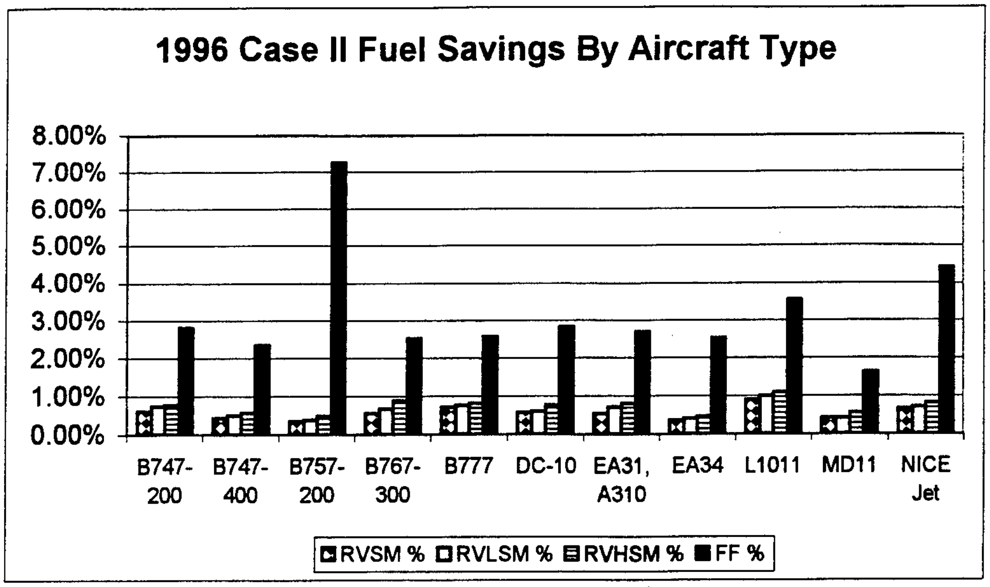
Appendix L

Complete Analysis of Case II Fuel Burn

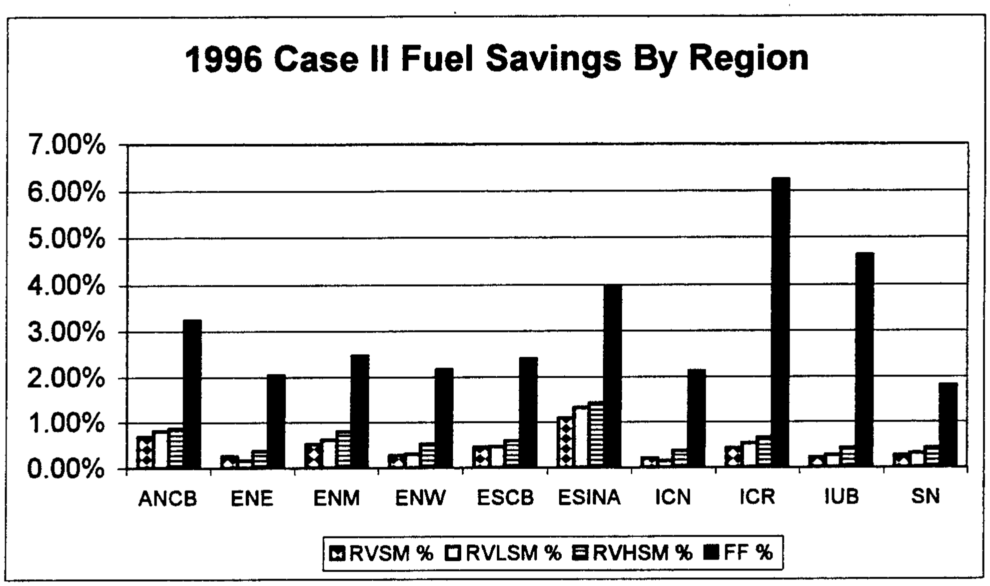
L1. 1996 Case II Fuel Results: Computed as 100% * (Baseline – Scenario / Scenario.

Day	RVSM %	RVLSM %	RVHSM %	FF %
Jan 4	0.64%	0.76%	0.81%	3.02%
Jan 15	0.70%	0.87%	0.93%	3.04%
Feb 4	0.78%	0.88%	0.91%	2.73%
Feb 15	0.35%	0.35%	0.43%	2.35%
Mar 4	0.37%	0.43%	0.67%	2.74%
Mar 15	0.37%	0.42%	0.48%	2.54%
Apr 4	0.49%	0.52%	0.68%	2.67%
Apr 15	0.57%	0.62%	0.78%	2.58%
May 4	0.43%	0.51%	0.80%	2.49%
May 15	0.41%	0.54%	0.82%	2.45%
Jun 4	0.22%	0.33%	0.57%	2.27%
Jun 15	0.66%	0.73%	0.78%	2.87%
Jul 4	0.41%	0.47%	0.68%	2.31%
Jul 15	0.45%	0.49%	0.59%	2.60%
Aug 4	1.08%	1.37%	1.36%	3.63%
Aug 15	0.58%	0.59%	0.75%	2.61%
Sep 4	1.09%	1.22%	1.20%	3.81%
Sep 15	0.31%	0.35%	0.49%	2.27%
Oct 4	0.52%	0.55%	0.65%	2.38%
Oct 15	0.77%	0.97%	1.05%	2.98%
Nov 4	0.40%	0.46%	0.88%	2.95%
Nov 15	0.64%	0.79%	1.03%	2.85%
Dec 4	0.63%	0.68%	0.70%	2.60%
Dec 15	0.63%	0.70%	0.81%	2.67%

a. Case II Fuel Savings by Aircraft Type for Year 1996



b. Case II Fuel Savings by Flight Regions for Year 1996



Appendix M
Sample FTM Output (GPSS/H)

M1. The following is the GPSS/H automated output produced from the January 4th simulation of the baseline system.

TABLE GANDER Number of Communications calls in the Gander Oceanic Region

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1718.0000	1.0360	2.1986	1778.7860	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0.	59.0000	3.4362	3.44	96.56	0.	-0.4712
1.0000	1192.0000	69.4234	72.86	27.14	0.9653	-0.0164
2.0000	258.0000	15.0262	87.89	12.11	1.9305	0.4385
3.0000	86.0000	5.0087	92.89	7.11	2.8958	0.8933
4.0000	51.0000	2.9703	95.86	4.14	3.8611	1.3482
5.0000	14.0000	0.8154	96.68	3.32	4.8263	1.8030
6.0000	18.0000	1.0483	97.73	2.27	5.7916	2.2578
7.0000	9.0000	0.5242	98.25	1.75	6.7569	2.7127
8.0000	5.0000	0.2912	98.54	1.46	7.7221	3.1675
9.0000	9.0000	0.5242	99.07	0.93	8.6874	3.6224
10.0000	2.0000	0.1165	99.18	0.82	9.6527	4.0772
11.0000	2.0000	0.1165	99.30	0.70	10.6179	4.5321
12.0000	1.0000	0.0582	99.36	0.64	11.5832	4.9869
13.0000	2.0000	0.1165	99.48	0.52	12.5484	5.4417
14.0000	3.0000	0.1747	99.65	0.35	13.5137	5.8966
...						
17.0000	2.0000	0.1165	99.77	0.23	16.4095	7.2611
18.0000	1.0000	0.0582	99.83	0.17	17.3748	7.7160
OVERFLOW	3.0000	0.17	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 35.0956

TABLE NEWYORK Number of Communications calls in the New York Oceanic Region

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
573.0000	3.0192	5.9704	1726.9970	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0.	68.0000	11.8881	11.89	88.11	0.	-0.5057
1.0000	217.0000	37.9371	49.83	50.17	0.3312	-0.3382
2.0000	111.0000	19.4056	69.23	30.77	0.6624	-0.1707
3.0000	54.0000	9.4406	78.67	21.33	0.9936	-0.0032
4.0000	26.0000	4.5455	83.22	16.78	1.3248	0.1643
5.0000	17.0000	2.9720	86.19	13.81	1.6561	0.3318
6.0000	15.0000	2.6224	88.81	11.19	1.9873	0.4993
7.0000	9.0000	1.5734	90.38	9.62	2.3185	0.6668
8.0000	7.0000	1.2238	91.61	8.39	2.6497	0.8343
9.0000	2.0000	0.3497	91.96	8.04	2.9809	1.0017
10.0000	4.0000	0.6993	92.66	7.34	3.3121	1.1692
11.0000	5.0000	0.8741	93.53	6.47	3.6433	1.3367
12.0000	3.0000	0.5245	94.06	5.94	3.9745	1.5042
13.0000	4.0000	0.6993	94.76	5.24	4.3057	1.6717
14.0000	2.0000	0.3497	95.10	4.90	4.6370	1.8392
...						
16.0000	2.0000	0.3497	95.45	4.55	5.2994	2.1742
17.0000	2.0000	0.3497	95.80	4.20	5.6306	2.3417
18.0000	3.0000	0.5245	96.33	3.67	5.9618	2.5092
OVERFLOW	21.0000	3.67	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 27.4180

TABLE SHANWICK Number of Communications calls in the Shanwick Oceanic Region

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1670.0000	1.1332	5.6539	1891.3483	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0.	122.0000	7.3098	7.31	92.69	0.	-0.2004
1.0000	1134.0000	67.9449	75.25	24.75	0.8824	-0.0236
2.0000	256.0000	15.3385	90.59	9.41	1.7649	0.1533
3.0000	81.0000	4.8532	95.45	4.55	2.6473	0.3302
4.0000	24.0000	1.4380	96.88	3.12	3.5298	0.5070
5.0000	15.0000	0.8987	97.78	2.22	4.4122	0.6839
6.0000	7.0000	0.4194	98.20	1.80	5.2946	0.8608
7.0000	7.0000	0.4194	98.62	1.38	6.1771	1.0376
8.0000	6.0000	0.3595	98.98	1.02	7.0595	1.2145
9.0000	1.0000	0.0599	99.04	0.96	7.9420	1.3914
...						
11.0000	1.0000	0.0599	99.10	0.90	9.7068	1.7451
...						
13.0000	3.0000	0.1797	99.28	0.72	11.4717	2.0989
14.0000	2.0000	0.1198	99.40	0.60	12.3541	2.2757
15.0000	1.0000	0.0599	99.46	0.54	13.2366	2.4526
...						
OVERFLOW	9.0000	0.54	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 56.5727

TABLE REYKJ Number of Communications calls in the Reykjavik Oceanic Region

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
288.0000	5.7853	15.9979	1660.3687	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0.	2.0000	0.6969	0.70	99.30	0.	-0.3616
1.0000	86.0000	29.9652	30.66	69.34	0.1729	-0.2991
2.0000	51.0000	17.7700	48.43	51.57	0.3457	-0.2366
3.0000	27.0000	9.4077	57.84	42.16	0.5186	-0.1741
4.0000	14.0000	4.8780	62.72	37.28	0.6914	-0.1116
5.0000	19.0000	6.6202	69.34	30.66	0.8643	-0.0491
6.0000	14.0000	4.8780	74.22	25.78	1.0371	0.0134
7.0000	11.0000	3.8328	78.05	21.95	1.2100	0.0759
8.0000	8.0000	2.7875	80.84	19.16	1.3828	0.1384
9.0000	7.0000	2.4390	83.28	16.72	1.5557	0.2009
10.0000	4.0000	1.3937	84.67	15.33	1.7285	0.2635
11.0000	5.0000	1.7422	86.41	13.59	1.9014	0.3260
12.0000	5.0000	1.7422	88.15	11.85	2.0742	0.3885
13.0000	4.0000	1.3937	89.55	10.45	2.2471	0.4510
14.0000	3.0000	1.0453	90.59	9.41	2.4199	0.5135
15.0000	3.0000	1.0453	91.64	8.36	2.5928	0.5760
16.0000	7.0000	2.4390	94.08	5.92	2.7657	0.6385
17.0000	1.0000	0.3484	94.43	5.57	2.9385	0.7010
18.0000	2.0000	0.6969	95.12	4.88	3.1114	0.7635
OVERFLOW	14.0000	4.88	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 44.6007

TABLE SANTAM Number of Communications calls in the Santa Maria Oceanic Region

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
546.0000	3.3284	9.3153	1813.9596	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0.	15.0000	2.7523	2.75	97.25	0.	-0.3573
1.0000	221.0000	40.5505	43.30	56.70	0.3004	-0.2500
2.0000	113.0000	20.7339	64.04	35.96	0.6009	-0.1426
3.0000	55.0000	10.0917	74.13	25.87	0.9013	-0.0353
4.0000	40.0000	7.3394	81.47	18.53	1.2018	0.0721
5.0000	24.0000	4.4037	85.87	14.13	1.5022	0.1795

6.0000	15.0000	2.7523	88.62	11.38	1.8027	0.2868
7.0000	11.0000	2.0183	90.64	9.36	2.1031	0.3942
8.0000	9.0000	1.6514	92.29	7.71	2.4036	0.5015
9.0000	6.0000	1.1009	93.39	6.61	2.7040	0.6089
10.0000	6.0000	1.1009	94.50	5.50	3.0045	0.7162
11.0000	1.0000	0.1835	94.68	5.32	3.3049	0.8236
12.0000	4.0000	0.7339	95.41	4.59	3.6054	0.9309
13.0000	2.0000	0.3670	95.78	4.22	3.9058	1.0383
...						
15.0000	4.0000	0.7339	96.51	3.49	4.5067	1.2530
...						
18.0000	2.0000	0.3670	96.88	3.12	5.4081	1.5750
OVERFLOW	17.0000	3.12	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 38.9422

TABLE COMITA Number of Communication Calls in the NAT

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
4795.0000	0.3945	1.2080	1891.3483	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
10.0000	4783.0000	99.7705	99.77	0.23	25.3470	7.9518
20.0000	6.0000	0.1252	99.90	0.10	50.6940	16.2302
30.0000	4.0000	0.0834	99.98	0.02	76.0410	24.5086
...						
50.0000	1.0000	0.0209	100.00	0.00	126.7350	41.0654

TABLE TBSTEP Number of Step Climbs Granted in the NAT

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
54.0000	30.9065	33.9918	1638.0456	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
2.0000	7.0000	13.2075	13.21	86.79	0.0647	-0.8504
4.0000	3.0000	5.6604	18.87	81.13	0.1294	-0.7916
6.0000	4.0000	7.5472	26.42	73.58	0.1941	-0.7327
8.0000	3.0000	5.6604	32.08	67.92	0.2588	-0.6739
10.0000	3.0000	5.6604	37.74	62.26	0.3236	-0.6150
...						
14.0000	2.0000	3.7736	41.51	58.49	0.4530	-0.4974
16.0000	4.0000	7.5472	49.06	50.94	0.5177	-0.4385
18.0000	1.0000	1.8868	50.94	49.06	0.5824	-0.3797
20.0000	2.0000	3.7736	54.72	45.28	0.6471	-0.3209
...						
24.0000	2.0000	3.7736	58.49	41.51	0.7765	-0.2032
26.0000	1.0000	1.8868	60.38	39.62	0.8412	-0.1443
28.0000	2.0000	3.7736	64.15	35.85	0.9060	-0.0855
...						
32.0000	1.0000	1.8868	66.04	33.96	1.0354	0.0322
34.0000	1.0000	1.8868	67.92	32.08	1.1001	0.0910
36.0000	1.0000	1.8868	69.81	30.19	1.1648	0.1498
...						
40.0000	2.0000	3.7736	73.58	26.42	1.2942	0.2675
42.0000	1.0000	1.8868	75.47	24.53	1.3589	0.3264
...						
50.0000	1.0000	1.8868	77.36	22.64	1.6178	0.5617
...						
60.0000	2.0000	3.7736	81.13	18.87	1.9413	0.8559
62.0000	2.0000	3.7736	84.91	15.09	2.0060	0.9147
...						
66.0000	1.0000	1.8868	86.79	13.21	2.1355	1.0324
...						
76.0000	1.0000	1.8868	88.68	11.32	2.4590	1.3266
...						
OVERFLOW	6.0000	11.32	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 106.6219

TABLE TBSTRQ Number of Step Climbs Requested in the NAT

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
105.0000	15.7504	20.2475	1638.0456	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
2.0000	12.0000	11.5385	11.54	88.46	0.1270	-0.6791
4.0000	15.0000	14.4231	25.96	74.04	0.2540	-0.5803
6.0000	9.0000	8.6538	34.62	65.38	0.3809	-0.4816
8.0000	14.0000	13.4615	48.08	51.92	0.5079	-0.3828
10.0000	7.0000	6.7308	54.81	45.19	0.6349	-0.2840
12.0000	3.0000	2.8846	57.69	42.31	0.7619	-0.1852
14.0000	7.0000	6.7308	64.42	35.58	0.8889	-0.0865
16.0000	6.0000	5.7692	70.19	29.81	1.0158	0.0123
18.0000	3.0000	2.8846	73.08	26.92	1.1428	0.1111
20.0000	3.0000	2.8846	75.96	24.04	1.2698	0.2099
22.0000	2.0000	1.9231	77.88	22.12	1.3968	0.3087
24.0000	3.0000	2.8846	80.77	19.23	1.5238	0.4074
26.0000	3.0000	2.8846	83.65	16.35	1.6507	0.5062
28.0000	1.0000	0.9615	84.62	15.38	1.7777	0.6050
30.0000	1.0000	0.9615	85.58	14.42	1.9047	0.7038
32.0000	2.0000	1.9231	87.50	12.50	2.0317	0.8025
34.0000	1.0000	0.9615	88.46	11.54	2.1587	0.9013
36.0000	1.0000	0.9615	89.42	10.58	2.2857	1.0001
38.0000	1.0000	0.9615	90.38	9.62	2.4126	1.0989
40.0000	2.0000	1.9231	92.31	7.69	2.5396	1.1977
42.0000	1.0000	0.9615	93.27	6.73	2.6666	1.2964
...						
48.0000	1.0000	0.9615	94.23	5.77	3.0475	1.5928
50.0000	1.0000	0.9615	95.19	4.81	3.1745	1.6915
52.0000	1.0000	0.9615	96.15	3.85	3.3015	1.7903
...						
76.0000	1.0000	0.9615	97.12	2.88	4.8253	2.9757
...						
OVERFLOW	3.0000	2.88	100.00	0.00		

AVERAGE VALUE OF OVERFLOW IS 100.7941

TABLE CRITA1 Number of Conflict Resolutions performed in the NAT

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1251.0000	0.9752	4.4333	1219.0000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
5.0000	1201.0000	96.0800	96.08	3.92	5.1272	0.9079
10.0000	27.0000	2.1600	98.24	1.76	10.2543	2.0357
15.0000	6.0000	0.4800	98.72	1.28	15.3815	3.1635
20.0000	3.0000	0.2400	98.96	1.04	20.5086	4.2913
25.0000	4.0000	0.3200	99.28	0.72	25.6358	5.4191
30.0000	3.0000	0.2400	99.52	0.48	30.7629	6.5470
...						
40.0000	1.0000	0.0800	99.60	0.40	41.0172	8.8026
45.0000	3.0000	0.2400	99.84	0.16	46.1444	9.9304
...						
55.0000	1.0000	0.0800	99.92	0.08	56.3987	12.1861
...						
85.0000	1.0000	0.0800	100.00	0.00	87.1616	18.9530

TABLE CDITER Number of Conflicts Detected in the NAT

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
345.0000	3.5436	7.9020	1219.0000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN

5.0000	295.0000	85.7558	85.76	14.24	1.4110	0.1843
10.0000	27.0000	7.8488	93.60	6.40	2.8220	0.8171
15.0000	6.0000	1.7442	95.35	4.65	4.2330	1.4498
20.0000	3.0000	0.8721	96.22	3.78	5.6440	2.0826
25.0000	4.0000	1.1628	97.38	2.62	7.0550	2.7153
30.0000	3.0000	0.8721	98.26	1.74	8.4660	3.3481
...						
40.0000	1.0000	0.2907	98.55	1.45	11.2879	4.6136
45.0000	3.0000	0.8721	99.42	0.58	12.6989	5.2463
...						
55.0000	1.0000	0.2907	99.71	0.29	15.5209	6.5118
...						
85.0000	1.0000	0.2907	100.00	0.00	23.9869	10.3084

Appendix N

Sample Fuel Burn Output

N1. The following is a sample of the fuel consumption output for January 4, 1996 simulation of the baseline system. The columns contain the following.

a. Flight number (assigned numerically as aircraft enter the system)

b. Aircraft type (assigned by modeler)

c. Total Fuel Consumed (lbs)

d. Direction code (0=east, 1=west)

e. Civilian/Military code (0=civilian, 1=military)

f. Total flight time (min)

2	1	22283.129	0	0	96.37
9	9	32043.356	0	0	115.37
4	1	38763.548	0	0	184.82
11	8	13940.092	0	0	95.15
6	1	93909.736	0	0	506.63
7	7	146151.312	0	0	493.69
8	1	93123.159	0	0	506.85
1	2	226646.729	1	0	473.28
3	2	219227.834	1	0	477.15
10	1	73936.734	0	1	393.09
12	1	98930.833	0	0	510.73
121	8	14461.424	0	0	104.5
19	1	78870.912	0	0	403.67
16	1	93885.04	0	0	504.08
134	3	40330.872	0	0	100.64
5	6	148156.23	1	0	381.38
14	3	108089.066	0	0	372.34
15	2	157886.793	0	0	348.78
181	1	21188.357	1	0	103.18
20	2	174006.395	0	0	411.41
24	2	154592.409	0	0	374.01
18	1	76883.481	0	0	394.88
31	2	200927.077	0	0	462.53
21	1	85759.925	0	0	485.33
26	2	167681.016	0	0	426.49
23	2	158484.406	0	0	328.66
25	2	167255.456	0	0	399.68
27	1	62668.284	0	0	401.76
79	2	212465.933	0	0	493.46
22	1	68587.108	0	0	403.79
44	3	133430.293	0	0	404.4
215	6	71320.688	0	0	158.41
43	3	158574.933	0	0	439.1
17	10	7383.729	0	1	347.48
32	2	152947.541	0	0	397.23
30	7	91235.103	0	0	327.08

59	7	110087.353	0	0	396.82
29	9	85718.973	0	0	369.53
37	4	128884.148	0	0	423.83
62	7	84121.854	0	0	336.99
53	1	73521.472	0	0	410.64
65	2	166541.921	0	0	411.88
49	4	105929.363	0	0	330.49
46	2	224590.504	0	0	496.62
35	1	87082.103	0	0	411.21
34	2	138200.578	0	0	358.12
36	2	180337.691	0	0	457.96
76	9	76637.708	0	0	264.15
57	5	64492.402	1	0	323.27
33	3	127646.232	0	0	409.43
78	7	92758.932	0	0	334.74
38	1	74212.131	0	0	400.34
80	11	88664.753	0	0	406.83
81	11	91129.098	0	0	395.83
39	3	115505.55	0	0	363.65
140	6	193847.375	0	0	531.65
48	1	84847.308	0	0	455.65
61	8	48017.875	0	0	402.66
91	11	80617.906	0	0	332.59
40	10	7767.481	0	0	375.99
92	9	110540.109	0	0	395.29
86	8	56031.505	0	0	446.8
101	2	143674.045	0	0	321.61
66	2	194513.989	0	0	469.67
182	1	36297.199	1	0	166.7
97	2	129307.054	0	0	362.46
114	2	156276.962	0	0	414.32
69	2	187613.97	0	0	397.24
99	1	72245.929	0	0	380.61
67	7	114830.185	0	0	400.3
84	1	100732.83	0	0	548.58
58	8	45940.144	0	0	395
110	9	110231.879	0	0	361.15
159	2	221311.984	0	0	513.62
112	7	85326.358	0	0	312.04
95	2	138646.99	1	0	319.15
74	1	81953.377	0	0	466.78
82	2	162854.189	0	0	401.74
72	1	57872.352	1	0	335.63
45	10	10770.17	0	0	512.51
63	1	79440.957	1	0	510.02
108	3	142532.74	0	0	500.74
128	2	183715.895	0	0	408.76
137	2	126031.722	0	0	324.06
135	7	142001.795	0	0	468.87
148	7	82774.502	0	0	285.11
89	3	96714.033	0	0	357.32
105	2	168842.689	0	0	348.47
149	9	93741.14	0	0	360.27
123	1	82108.75	0	0	438.11
131	3	157294.638	0	0	507.49

226	8	63820.403	0	0	578.25
96	5	71464.689	0	0	363.98
158	7	108068.633	0	0	395.83
102	3	136371.64	0	0	452.09
124	8	61637.237	0	0	505.44
154	9	71499.768	0	0	309.89
161	1	64877.01	0	0	325.81
170	3	117136.292	0	0	450.85
166	1	66104.35	0	0	337.65
55	6	152140.798	0	0	398.09
118	2	143154.23	0	0	391.56
165	1	89204.577	0	0	435.16
47	2	177624.322	0	0	453.38
77	4	122264.86	1	0	416.86
109	1	87573.92	0	0	467.12
120	1	88183.265	0	0	429.38
204	1	87921.946	0	0	515.49
133	3	111667.344	0	0	299.78
173	10	7293.362	0	0	325.05
42	9	86447.595	0	0	438.04
73	8	51779.638	1	0	497.98
184	2	129515.259	0	0	301.02
150	7	113220.533	0	0	333.42
129	7	134771.824	0	0	443.79
116	1	65977.708	0	0	401.9
127	2	188984.646	0	0	447.77
41	1	67650.907	0	0	420.23
52	1	73612.514	0	0	432.07
187	1	100911.051	0	0	485.24
64	2	163273.808	0	0	435.47
186	1	85361.921	0	0	459.62
171	1	93037.548	0	0	424.21
176	1	60255.488	0	0	328.04
193	11	96004.901	0	0	357.86
163	2	228188.626	0	0	517.74
54	1	75328.201	0	0	429.42
139	6	136757.905	0	0	357.93
234	8	39131.569	0	0	302.37
122	8	43497.928	0	0	353.71
142	4	102702.82	0	0	362.91
143	1	72853.723	0	0	401.34
185	1	87600.902	0	0	451.5
177	1	83929.478	0	0	451.36
151	1	74472.079	0	0	357.3
51	7	104589.905	0	0	453.82
60	1	63311.836	0	0	442.27
201	3	138080.257	0	0	376.03
192	3	141636.224	0	0	402.71
164	8	39175.825	0	0	319.73
145	9	96752.569	0	0	345.53
200	10	7228.861	0	0	321.4
56	8	44071.216	0	0	407.99
50	1	72918.861	0	1	437.48
179	1	104150.169	0	0	517.64
191	7	119078.092	0	0	467.76

183	1	89358.27	0	0	457.9
212	2	195781.211	0	0	458.53
68	1	73127.481	0	0	486.11
156	1	87447.671	0	0	467.13
153	1	86419.056	0	0	446.8
214	9	84679.311	0	0	336.91
175	2	142073.101	0	0	345.17
85	4	122331.309	0	0	469.68
93	2	131325.151	0	0	412.91
238	1	55589.014	0	0	282.79
224	6	158414.251	0	0	356.02
194	2	205528.593	0	0	488.38
70	2	159345.688	0	0	447.25
223	2	133445.321	0	0	282.78
75	1	64554.217	0	0	416.73
188	1	62556.118	0	0	344.76
106	2	186921.229	0	0	414.45
242	1	60617.545	0	0	282.61
218	10	8082.508	0	0	369.21
217	7	149476.22	0	0	464.65
83	1	60787.206	0	0	395.18
71	9	92185.016	0	0	437.77
203	2	172900.301	0	0	331.54
115	2	157090.664	0	0	363.11
178	1	75379.755	0	0	395.07
113	1	115032.264	0	1	704.11
98	3	134049.987	0	0	453.85
220	1	70491.762	0	0	390.12
87	10	8287.833	0	1	448.11
107	9	97284.947	0	0	404.86
189	3	114242.301	0	0	397.67
225	1	77947.722	0	0	384.15
213	9	215378.398	0	0	818.42
94	1	61623.721	0	0	410.18
88	2	188811.605	0	0	499.01
190	1	69352.391	0	0	409.25
229	1	66357.039	0	0	316.26
233	2	175247.613	0	0	374.48
13	3	198695.858	1	0	586.18
219	11	106834.648	0	0	476.12
216	2	163764.82	0	0	323.15
111	1	71448.124	0	0	422.32
119	5	66752.506	0	0	397.35
130	2	176301.331	0	0	507.51
104	11	88517.936	0	0	390.13
90	1	74732.156	0	0	423.71
100	1	83610.889	0	0	518.41
195	3	131866.445	0	0	438.37
103	2	169203.208	0	0	520.02
126	9	97919.573	0	0	541.92
267	2	127149.691	0	0	276.15
240	10	8366.639	0	0	384.78
155	6	117283.178	0	0	361.54
207	5	62046.679	0	0	371.06
251	6	230596.478	0	0	527.46

Appendix O

Sample Output from FPM

O1. The following represents a partial listing of output from the FPM of January 4, 2005. Each Flight Plan includes:

1. Sequential Number in the FE File
2. Day Code (0 indicates departure on day N-1, 1 indicates departure on day N)
3. Entry Time (minutes)
4. Direction (0=eastbound, 1=westbound)
5. Aircraft Type Code
6. Civilian / Military indicator (0=civilian, 1=military)
7. Mach Number (*1000)
8. NAT Entry latitude
9. NAT Entry Longitude
10. Latitude at 60W (= 999 if flight does not cross 60W)
11. Latitude at 50W (= 999 if flight does not cross 50W)
12. Latitude at 40W (= 999 if flight does not cross 40W)
13. Latitude at 30W (= 999 if flight does not cross 30W)
14. Latitude at 20W (= 999 if flight does not cross 20W)
15. Latitude at 15W (= 999 if flight does not cross 15W)
16. NAT Exit Latitude
17. NAT Exit Longitude
18. NAT Entry Flight Level
19. Flight Level at 60W (= 999 if flight does not cross 60W)
20. Flight Level at 50W (= 999 if flight does not cross 50W)
21. Flight Level at 40W (= 999 if flight does not cross 40W)
22. Flight Level at 30W (= 999 if flight does not cross 30W)
23. Flight Level at 20W (= 999 if flight does not cross 20W)
24. Flight Level at 15W (= 999 if flight does not cross 15W)
25. NAT Exit Flight Level
26. NAT Fuel (Pounds)
27. NAT Time
28. Track (all = RN)
29. Origin Airport Latitude
30. Origin Airport Longitude
31. Destination Airport Latitude
32. Destination Airport Longitude
33. Take off weight
34. Total Fuel burn
35. Total Time
36. Origin Airport Code
37. Destination Airport Code

```
   1 0 1418 0  1 0 800  44.53  61.41  45.00  45.00  45.00  46.00
48.00  49.00  50.00   8.00  35.00  35.00  35.00  37.00  37.00
37.00  39.00  39.00  38979.132812  14957.962891 RN 36.14 115.02
50.57  -6.02  354252.00 103635.359375  36535.414062 KLSV ETNG
   2 0 1391 0  1 0 810  37.00  46.00 999.00 999.00  39.00  42.00
46.00  48.00  50.00   8.00  33.00 999.00 999.00  35.00  35.00
37.00  37.00  37.00  35031.265625  12393.004883 RN 12.11  68.57
52.18  -4.45  365216.00  94007.437500  30808.630859 TNCC EHAM
   3 1    1 0  9 0 820  37.00  46.00 999.00 999.00  39.00  41.00
44.00  45.00  47.00   8.45  35.00 999.00 999.00  37.00  37.00
37.00  39.00  39.00  43726.746094  11921.452148 RN 10.36  66.59
50.02  -8.33  514728.00 126059.835938  32220.552734 SVMI EDDF
   4 0 1391 0  1 0 800  37.00  46.00 999.00 999.00  39.00  41.00
43.00  44.00  45.00   9.00  31.00 999.00 999.00  33.00  33.00
33.00  35.00  35.00  35945.023438  11544.173828 RN 16.16  61.31
47.09   1.36  396304.00  85815.460938  25828.308594 TFFR LFRS
   5 1   37 0  9 0 830  66.58  50.00 999.00 999.00  66.00  65.00
63.00  61.00  58.00  10.00  33.00 999.00 999.00  35.00  35.00
35.00  37.00  37.00  36268.382812   8858.588867 RN 64.49 147.52
49.00  -2.32  545897.00 135683.234375  30844.482422 PAFA LFPG
   6 1    7 0  6 0 850  37.00  46.00 999.00 999.00  39.00  41.00
44.00  45.00  47.00   8.45  33.00 999.00 999.00  35.00  35.00
35.00  37.00  37.00  70757.125000  11453.180664 RN 10.36  66.59
50.02  -8.33  801019.00 206812.437500  30818.943359 SVMI EDDF
   7 1   35 0  2 0 860  66.58  50.00 999.00 999.00  66.00  65.00
63.00  61.00  58.00  10.00  33.00 999.00 999.00  35.00  35.00
35.00  37.00  37.00  58647.960938   8570.184570 RN 64.49 147.52
49.00  -2.32  746402.00 222919.281250  29837.064453 PAFA LFPG
   8 0 1350 0  1 0 820  50.38  54.48 999.00  53.00  58.00  62.00
64.00  64.00  64.39  14.16  33.00 999.00  33.00  33.00  35.00
35.00  35.00  35.00  36890.476562  11513.599609 RN 40.38  73.46
55.58 -37.25  371044.00  94562.968750  29552.849609 KJFK UUEE
   9 0 1326 0  1 0 810  44.53  57.42 999.00  44.00  43.00  42.00
42.00  42.00  41.55   9.21  33.00 999.00  33.00  33.00  33.00
35.00  37.00  37.00  41745.343750  13562.076172 RN 45.40  74.02
32.00 -34.53  363005.00 100453.640625  33522.585938 CYMX LLBG
  10 0 1376 0  1 0 810  52.15  52.28 999.00  54.00  59.00  62.00
64.00  64.00  64.39  14.16  33.00 999.00  33.00  33.00  33.00
35.00  35.00  35.00  34126.656250  10701.937500 RN 40.38  73.46
55.58 -37.25  382233.00  95614.000000  29894.974609 KJFK UUEE
  11 1   80 0  6 0 850  66.58  50.00 999.00 999.00  66.00  65.00
63.00  62.00  60.00  10.00  33.00 999.00 999.00  35.00  35.00
35.00  35.00  35.00  51246.101562   8065.585938 RN 64.49 147.52
50.02  -8.33  824961.00 210978.578125  30412.035156 PAFA EDDF
  12 1   16 0  1 0 800  37.00  46.00 999.00 999.00  39.00  41.00
44.00  45.00  47.00   8.45  33.00 999.00 999.00  35.00  35.00
35.00  35.00  35.00  35135.332031  12057.326172 RN 16.16  61.31
48.43  -2.21  373309.00  84455.046875  27163.966797 TFFR LFPO
  13 0 1343 0 11 0 840  44.53  57.42 999.00  45.00  45.00  45.00
45.00  45.00  45.00   9.00  39.00 999.00  39.00  39.00  39.00
39.00  39.00  39.00  43397.562500  13307.664062 RN 40.38  73.46
37.53 -23.43  406009.00  97146.046875  28697.705078 KJFK LGAT
  14 1  133 0 11 0 840  36.57  25.52 999.00 999.00 999.00 999.00
39.00  42.00  45.00   9.00  37.00 999.00 999.00 999.00 999.00
37.00  39.00  39.00  22259.250000   5968.408203 RN  4.49  52.21
49.00  -2.32  527678.00 114730.820312  27948.210938 SOCA LFPG
  15 1   36 0  9 0 820  37.00  46.00 999.00 999.00  39.00  41.00
44.00  45.00  47.00   8.45  35.00 999.00 999.00  37.00  37.00
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37.00  39.00  39.00  44547.742188  11913.103516 RN 14.35  60.59
48.43  -2.21  512684.00 110051.062500  27678.599609 TFFF LFPO
  16 0 1301 1  6 0 840  54.02   6.46  55.00  57.00  58.00  58.00
57.00  56.00  53.30  67.00  31.00  35.00  35.00  35.00  35.00
33.00  33.00  35.00  94073.820312  15051.970703 RN 52.49   1.19
38.10  85.44  736415.00 164502.593750  26580.257812 EGNX KSDF
  17 1   18 0  2 0 850  37.00  46.00 999.00 999.00  39.00  41.00
43.00  44.00  45.00   9.00  31.00 999.00 999.00  33.00  33.00
35.00  35.00  35.00  78978.164062  11023.482422 RN 16.16  61.31
47.09   1.36  767286.00 190317.078125  24681.939453 TFFR LFRS
  18 1   33 0  1 0 800  37.00  46.00 999.00 999.00  39.00  41.00
43.00  44.00  45.00   9.00  31.00 999.00 999.00  33.00  33.00
33.00  35.00  35.00  37055.621094  11602.679688 RN 16.16  61.31
47.09   1.36  407268.00  88145.257812  25891.013672 TFFR LFRS
  19 0 1408 0  9 0 820  44.53  57.42 999.00  46.00  47.00  48.00
49.00  50.00  50.00  12.00  35.00 999.00  37.00  37.00  37.00
37.00  39.00  39.00  47209.972656  12691.694336 RN 39.02  84.39
50.02  -8.33  492249.00 101272.765625  26305.005859 KCVG EDDF
  20 0 1311 1  9 0 810  54.02   6.46  56.00  57.00  58.00  58.00
57.00  56.00  54.48  66.45  37.00  39.00  39.00  37.00  37.00
37.00  37.00  39.00  49519.371094  15595.776367 RN 52.49   1.19
38.10  85.44  400813.00  89576.335938  28305.011719 EGNX KSDF
  21 1   86 0  1 0 810  37.00  46.00 999.00 999.00  39.00  41.00
44.00  46.00  49.00   8.00  33.00 999.00 999.00  35.00  35.00
35.00  35.00  35.00  36369.843750  12298.938477 RN 12.11  68.57
52.18  -4.45  382944.00  98337.359375  30837.208984 TNCC EHAM
  22 1  144 0  9 0 810  66.58  50.00 999.00 999.00  67.00  66.00
62.00  61.00  58.00  10.00  33.00 999.00 999.00  33.00  35.00
37.00  37.00  37.00  34982.945312   9140.634766 RN 61.10 149.59
51.28   0.27  548856.00 132253.843750  31964.337891 PANC EGLL
  23 0 1433 0  9 0 820  44.53  61.41  45.00  46.00  47.00  48.00
50.00  51.00  52.15   5.38  33.00  35.00  35.00  35.00  37.00
37.00  37.00  37.00  61873.167969  15238.170898 RN 26.32  81.45
51.16  -6.45  545640.00 117174.625000  27580.746094 KRSW EDDL
  24 1   42 0  2 0 830  40.50  51.48 999.00  41.00  43.00  45.00
47.00  48.00  49.04  11.44  33.00 999.00  35.00  35.00  37.00
37.00  37.00  37.00  71496.710938  11672.587891 RN 19.45  70.33
51.16  -6.45  689316.00 184722.187500  28067.353516 MDPP EDDL
  25 1   63 0  1 0 800  37.00  46.00 999.00 999.00  39.00  41.00
44.00  45.00  47.00   8.45  33.00 999.00 999.00  33.00  33.00
35.00  35.00  35.00  35919.042969  11968.697266 RN 14.35  60.59
48.43  -2.21  385482.00  88988.109375  27789.605469 TFFF LFPO
  26 1   15 0  1 0 800  44.53  57.42 999.00  45.00  45.00  45.00
45.00  45.00  45.00   9.00  35.00 999.00  35.00  35.00  35.00
37.00  37.00  37.00  37182.152344  13493.267578 RN 41.58  87.54
41.48 -12.15  345177.00  83821.210938  29307.417969 KORD LIRF
  27 1  180 0  6 0 850  44.53  61.41  45.00  46.00  47.00  48.00
50.00  51.00  51.00  12.00  33.00  35.00  35.00  37.00  37.00
37.00  39.00  39.00  73683.617188  12879.136719 RN 33.56 118.24
51.16  -6.45  773729.00 227639.953125  35908.925781 KLAX EDDL
  28 1   22 0  1 0 800  44.53  57.42 999.00  45.00  45.00  46.00
48.00  49.00  50.00   8.00  35.00 999.00  35.00  37.00  37.00
37.00  39.00  39.00  37189.167969  13835.221680 RN 33.38  84.25
48.06 -16.34  335826.00  82280.835938  29514.775391 KATL LOWW
  29 1   98 0  9 0 810  44.53  57.42 999.00  45.00  45.00  46.00
48.00  49.00  50.00   8.00  37.00 999.00  37.00  37.00  37.00
39.00  39.00  39.00  44688.613281  13682.332031 RN 32.53  97.02
51.08   0.11  455166.00 101739.320312  29117.664062 KDFW EGKK
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  30 1  202 0  1 0 800  44.53  61.41  45.00  45.00  45.00  46.00
48.00  49.00  50.00   8.00  33.00  35.00  35.00  35.00  35.00
35.00  37.00  37.00  41978.015625  14621.658203 RN 37.37 122.22
51.28   0.27  399515.00 115308.468750  36204.726562 KSFO EGLL
  31 1   86 0  6 0 850  44.53  57.42 999.00  45.00  45.00  46.00
48.00  49.00  50.00   8.00  37.00 999.00  37.00  37.00  37.00
39.00  39.00  39.00  68123.125000  13137.491211 RN 29.58  95.20
51.08   0.11  660189.00 156448.781250  27528.574219 KIAH EGKK
  32 1   94 0  9 0 820  37.00  46.00 999.00 999.00  39.00  41.00
44.00  45.00  47.00   8.45  35.00 999.00 999.00  35.00  37.00
37.00  37.00  37.00  46179.671875  11867.580078 RN 14.35  60.59
48.43  -2.21  532587.00 114240.468750  27629.066406 TFFF LFPO
  33 1   98 0  1 0 800  37.00  46.00 999.00 999.00  38.00  39.00
40.00  41.00  41.55   9.21  35.00 999.00 999.00  37.00  37.00
37.00  39.00  39.00  30346.539062  11509.576172 RN 14.35  60.59
43.26  -5.13  338458.00  81345.195312  28931.855469 TFFF LFML
  34 0 1405 0 11 0 840  44.53  57.42 999.00  47.00  49.00  51.00
53.00  54.00  54.13  13.00  35.00 999.00  37.00  37.00  39.00
39.00  39.00  39.00  47500.585938  12357.925781 RN 40.41  74.10
55.36 -12.38  497486.00  93611.093750  23468.972656 KEWR EKCH
  35 0 1409 0  8 1 800  44.53  57.42 999.00  45.00  45.00  46.00
48.00  49.00  50.00   8.00  33.00 999.00  35.00  35.00  35.00
35.00  35.00  35.00  30037.410156  13959.900391 RN 40.01  74.36
50.02  -8.34  248739.00  52804.562500  23580.339844 KWRI EDAF
  36 1  211 0  1 0 810  66.58  50.00 999.00 999.00  67.00  66.00
66.00  65.00  64.39  14.16  31.00 999.00 999.00  33.00  33.00
35.00  35.00  35.00  20720.375000   6850.781250 RN 47.26 122.18
55.36 -12.38  394767.00 109211.851562  33388.308594 KSEA EKCH
  37 1   92 0  1 0 800  40.50  51.48 999.00  41.00  41.00  40.00
40.00  40.00  40.57   9.03  33.00 999.00  35.00  35.00  35.00
35.00  37.00  37.00  35232.980469  12400.789062 RN 23.01  81.26
40.28   3.33  365608.00  80830.570312  26415.658203 MUVR LEMD
  38 1  102 0  9 0 820  44.53  57.42 999.00  45.00  45.00  46.00
47.00  48.00  49.00   8.00  37.00 999.00  37.00  37.00  37.00
39.00  39.00  39.00  44348.292969  13514.357422 RN 29.58  95.20
49.00  -2.32  442825.00 101791.460938  29181.191406 KIAH LFPG
  39 1   89 0  6 0 850  37.00  46.00 999.00 999.00  38.00  39.00
40.00  41.00  41.55   9.21  31.00 999.00 999.00  33.00  33.00
35.00  35.00  35.00  70208.742188  10787.867188 RN 14.35  60.59
43.37  -1.22  814798.00 182447.625000  25888.291016 TFFF LFBO
  40 1   57 0 11 0 830  44.53  57.42 999.00  44.00  43.00  42.00
41.00  41.00  40.59   8.16  37.00 999.00  39.00  39.00  39.00
39.00  39.00  39.00  46523.085938  13654.291016 RN 25.47  80.17
40.28   3.33  466859.00  92629.320312  25143.263672 KMIA LEMD
  41 1  103 0  1 0 800  37.00  46.00 999.00 999.00  38.00  39.00
40.00  41.00  41.55   9.21  31.00 999.00 999.00  33.00  33.00
35.00  35.00  35.00  34671.488281  11359.284180 RN 14.35  60.59
43.37  -1.22  390900.00  89160.531250  27368.421875 TFFF LFBO
  42 0 1416 0  9 0 820  44.53  57.42 999.00  45.00  45.00  45.00
46.00  46.00  47.00   8.45  35.00 999.00  35.00  37.00  37.00
37.00  37.00  37.00  52088.078125  13538.724609 RN 40.41  74.10
45.38  -8.44  497571.00  93403.937500  23673.662109 KEWR LIMC
  43 1  206 0  7 0 830  44.53  61.41  45.00  46.00  47.00  48.00
49.00  50.00  50.00  12.00  33.00  35.00  35.00  35.00  37.00
37.00  37.00  37.00  55459.195312  13096.546875 RN 37.37 122.22
51.28   0.27  587896.00 166442.156250  35099.718750 KSFO EGLL
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